7 STRUCTURAL ORGANISATION IN ANIMALS —ANIMAL TISSUES

Levels of Structural Organisation of a Multicellular Animal

(a) **Chemical Level.** It is the lowest level of organisation. It includes all chemical substances essential for maintaining life. All these chemicals are made up of atoms. Atoms join together to form molecules.

(b) **Cellular Level.** The chemicals are put together to form the cellular level. Cells are the basic structural and functional units of an organism (living thing). Cells are of different types *i.e.*, muscle cells, nerve cells, etc. Cells are structurally and functionally differentiated into several types. Just as people of different professions such as farmers, physicians, engineers, carpenters, tailors, cobblers, traders, etc. run a human society, various types of cells, specialized for different function or functions like protection, support, locomotion, secretion, nutrition, absorption, transportation of materials, respiration, excretion, reproduction, sensory, reception, impulse conduction, etc. run the life of a multicellular organism. It is called **'division of labour'** amongst the cells.

(c) **Tissue Level.** The cells that are similar in structure, origin and function form a tissue. There are four main types of tissues : epithelial, connective, muscular and nervous. The epithelial tissues protect the surfaces of the organ and form glands. The connective tissues join and support other tissues. The muscular tissues bring about movements of body parts and locomotion. The nervous tissues control and coordinate various body parts.

(d) **Organ Level.** An **organ** may be defined as a structure of the body which performs a specific function. It is appropriate to consider an organ as the combination of tissues into a unit for the performance of a specific function or a series of related functions. An artery may be taken as a typical example of an organ. The specific function of an artery is to distribute blood to the tissues of the body.

(e) **System Level.** Several organs constitute an **organ-system**. The various systems of the body are as follows:

1. **Integumentary system.** It is made up of skin which is mainly protective, sensory and secretory in function.
2. **Muscular system.** It is composed of various muscles and is responsible for external and internal movements of the body and body parts.
3. **Skeletal system.** It is constituted by the bones and cartilages. It is supporting and protective in function.
4. **Digestive system.** It includes alimentary canal and digestive glands. The ingestion, digestion and absorption of food and egestion of faecal matter take place by this system.

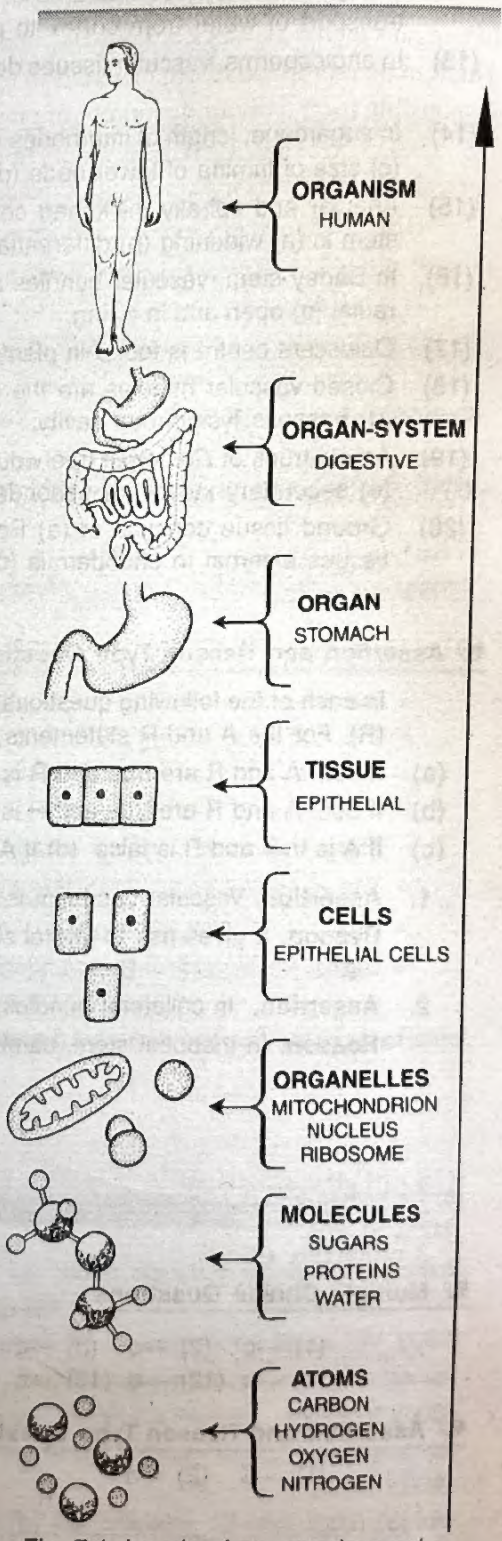


Fig. 7.1. Levels of structural organization that compose the human body.

5. **Circulatory system.** It includes blood vascular system (also called blood circulatory system) and lymphatic system. **Blood vascular system** comprises heart, blood vessels and blood. **Lymphatic system** consists of lymph capillaries, lymph vessels, lymphatic ducts and lymph nodes and lymph. Circulatory system transports various materials from one place to another.

6. **Respiratory system.** It includes the external nares (nostrils), nasal cavity, internal nares, pharynx, larynx, trachea and lungs. Gaseous exchange occurs by this system.

7. **Excretory system.** It consists of kidneys, ureters, urinary bladder and urethra. It removes metabolic wastes from the body.

8. **Reproductive system.** It comprises male and female reproductive organs. Human male reproductive organs include testes, epididymus, vasa deferentia, seminal vesicles, prostate, Cowper's glands and penis. The female reproductive organs are ovaries, Fallopian tubes, uterus and vagina. The reproductive system is responsible for the multiplication of organisms.

9. **Nervous system.** It comprises the brain, spinal cord, cranial and spinal nerves and autonomic nervous system. This system controls and coordinates the different activities of the various body parts.

10. **Sensory system.** It includes sense organs such as eyes, ears, nose, tongue and skin. The organs of this system receive the senses and convey the same to the nervous system.

11. **Endocrine system.** It is formed of ductless glands whose secretions are known as **hormones,** which influence the various metabolic processes of the body. Hormones act as chemical messengers.

12. **Immune system.** It consists of the bone marrow, lymphatic nodes, spleen and white blood corpuscles. It provides the body against foreign microbes and chemicals.

(f) **Organismic Level.** All the parts of the body constitute the total **organism**— one living individual. Organismic level is the highest level of structural organization.

What is a tissue ?

A tissue (Fr. *tissue*, woven) is a group of one or more types of cells and their intercellular substance that perform a particular function.

- The word **"tissue"** was given by a French anatomist and physiologist **Bichat** (1771–1802). The term tissue was already coined by **N. Grew** (1682) in connection with plant anatomy.
- An Italian scientist **Marcello Malpighi** (1628–1694) founded a separate branch for the study of tissues. He is **"founder of histology"**.
- Study of tissues is called **histology**. (Gr. *histos* – tissue, *logos* – study).
- The term 'histology' was given by a German histologist **Mayer** (1819).
- Histology is also called **microscopic anatomy** (= **microanatomy**) .
- **Bichat** (1771–1802) is considered **"Father of Animal Histology"**.

Based on the location and function, the animal tissues are classified into four types.

Type	Origin	Function
1. **Epithelial tissue**	Ectoderm, endoderm, mesoderm.	Protection, secretion, absorption, excretion, reproduction.
2. **Connective tissue**	Mesoderm	Attachment, support, storage, protection, transport
3. **Muscular tissue**	Mesoderm	Movement of body parts and locomotion
4. **Nervous tissue**	Ectoderm	Control and coordination by nerve impulse

All the above-mentioned tissues are of regular occurrence in the body of a vertebrate and many of them can be seen in the invertebrates too.

I. EPITHELIAL TISSUES (= EPITHELIA)

An epithelium is a tissue composed of one or more layers of cells covering the external and internal surfaces of various body parts. Epithelial tissue also forms glands.

The term **"epithelium"** (sing. of epithelia) was given by a Dutch anatomist **Ruysch** (1638–1731) to refer to the fact that epithelial (Gr. *epi–* upon, *thelio–* grows) tissues grow upon other tissues.

Location. The epithelial tissues occur on external and internal exposed surfaces of the body parts where they form protective covering.

Origin. *Epithelial tissues evolved first and are also formed first in the embryo.* The epithelial tissues arise from all the three primary germ layers : **ectoderm, mesoderm** and **endoderm**, of the embryo. For example the epidermis of the skin from the ectoderm, coelomic epithelium from the mesoderm and epithelial lining of alimentary canal (= gut) from the endoderm.

Characteristic Features of Epithelial Tissues. Epithelial tissues consist of variously shaped cells closely arranged in one or more layers. There is little intercellular material between the cells. The cells are held together by intercellular junctions. The epithelial tissues usually rest on a thin noncellular **basement membrane**. *Usually blood vessels are absent in epithelial tissues.* However the underlying connective tissues are generally well supplied with blood vessels. Nutrients enter epithelial tissues from the underlying connective tissues by diffusing through the basement membrane. Nerve endings may penetrate the epithelial tissues. The epithelial tissues have a *good power of repair* (*regeneration*) after injury.

*A specialized epithelium, the **stria vascularis** of the cochlea of internal ear has blood capillaries within the thickness of the epithelium.*

Basement Membrane. As stated earlier the epithelial tissues usually lie on the noncellular basement membrane which consists of two layers.

(i) **Basal Lamina**. It is outer thin layer (near the epithelial cells), composed of mucopolysaccharides and glycoproteins, both secreted by epithelial cells. It is visible only with the electron microscope.

(ii) **Fibrous** or **Reticular Lamina**. It is inner thick layer, composed of collagen or reticular fibres of the underlying connective tissue. It is visible with light microscope.

The basement membrane provides elastic support. It also allows selective chemical exchange between epithelial tissues and surrounding blood vessels.

Specializations of the Plasma Membrane (= Cell membrane)

These specializations of plasma membrane are as follows :

(i) **Microvilli**. These are minute finger like processes (= projections) which arise from free surface of the epithelial cells. They increase the absorptive surface area of the cells. Microvilli are found in the intestinal epithelium.

(ii) **Stereocilia**. These are long, non-motile processes of the epithelial cells. They are found in the epithelium of epididymis and vas deferens (both are parts of male reproductive tract). They are also present in the hair cells of the internal ear.

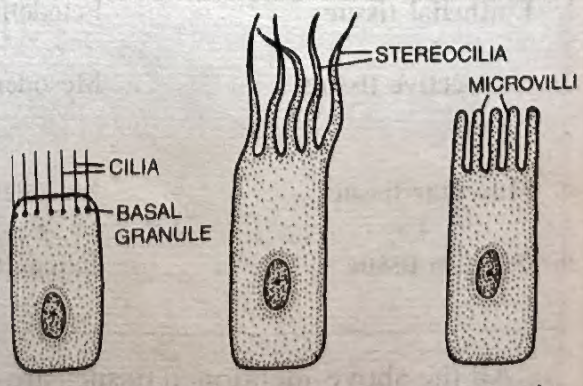


Fig. 7.2. Epithelial cells showing projections in the form of cilia, stereocilia and microvilli.

(iii) **Cilia and Flagella**. They arise from the basal granules. Outer covering of the cilia and flagella is continuous with the cell membrane. Cilia are present in the epithelium of respiratory tract, oviducts, etc. The cilia beat back and forward to propel the materials which come in contact with them. In the human body, only the spermatozoon (= sperm) has flagellum which helps in its locomotion.

(iv) **Endocytic, Pinocytotic** and **Exocytic Vesicles**. These vesicles are associated with endocytosis (cell eating), pinocytosis (cell drinking) and exocytosis (cell vomiting) respectively.

Specialized Junctions between Epithelial Cells

These are as follows :

(i) **Tight Junctions (= Zonula occludens)**. Plasma membranes in the apical parts of the adjacent epithelial cells become tightly packed together or are even fused to form the tight junctions. They check the flow of materials between the cells.

(ii) **Gap Junctions.** These also occur between adjacent epithelial cells. Gap junctions do not provide physical support but are meant for chemical exchange between adjacent cells.

(iii) **Adhering Junctions.** They perform cementing function to keep neighbouring cells together. Adhering junctions are of three types : zonula adherens, desmosomes (macula adherens) and hemidesmosomes.

(a) **Zonula adherens.** There is a dense plaque like structure on cytoplasmic side of each plasma membrane from which fine micro filaments of actin (protein) extend into the cytoplasm. There is no intercellular filaments between the adjacent cell membranes. There is an adhesive material at this point. They probably serve anchoring function.

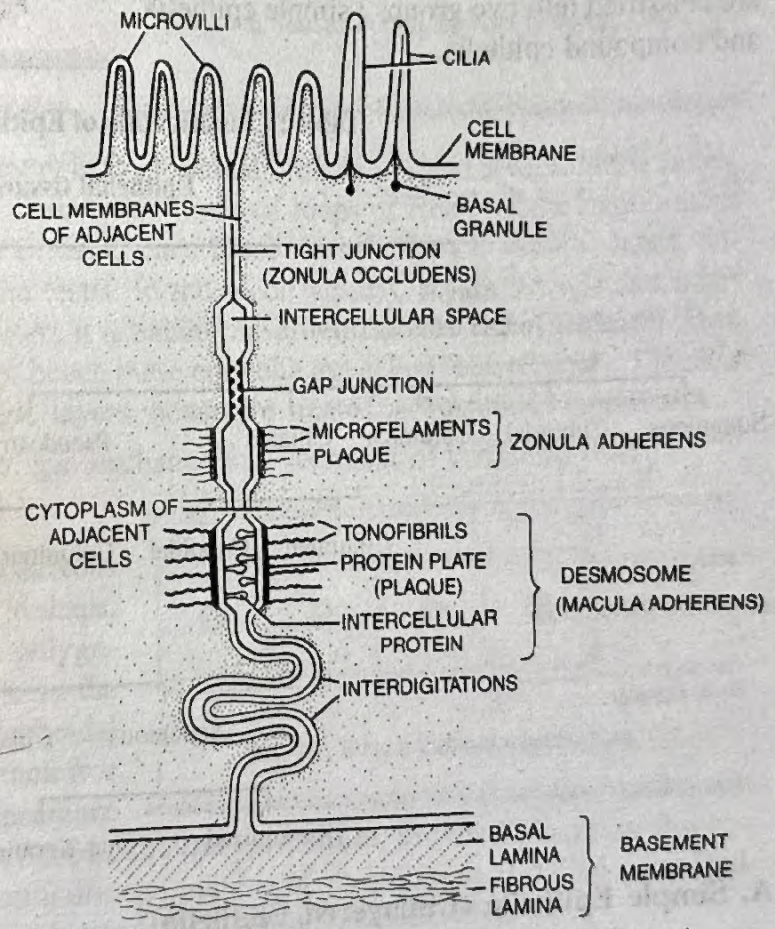


Fig. 7.3. Showing microvilli, cilia, cell junctions and basement membrane.

(b) **Desmosomes (= Macula adherens)**. These are like zonula adherens but are thicker and stronger and are disc like junctions. They have intercellular protein. The plaque-like structures (= protein plate) are much thicker. The microfilaments which extend from plaque-like structure into the cytoplasm are not of actin, but of a keratin like protein and these microfilaments are called **tonofibrils**. Desmosomes serve anchoring function.

(c) **Hemidesmosomes** (single sided desmosomes) are similar to desmosomes, but the

surface of each cell is slightly broader. *The nuclei are somewhat elongated* along the long axis of the cells. *Nuclei lie near the bases of the cells.* Certain cells of this epithelium contain **mucus** (a slimy substance) and are called **goblet** (or **mucous**) **cells** as they look like goblet. The epithelium containing mucus secreting cells, alongwith the under lying supporting connective tissue is called **mucosa** or **mucous membrane**. The latter is present in the stomach and intestine. The intestinal mucosa (= mucous membrane) has microvilli to increase the absorptive surface area and is called **brush-bordered columnar** epithelium which is highly absorptive.

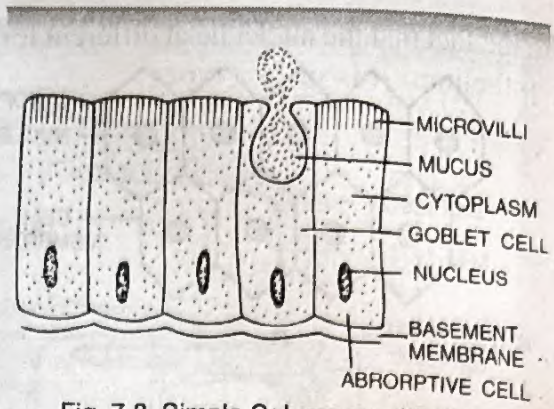


Fig. 7.8. Simple Columnar epithelium.

Location. It lines the stomach, intestine, gall bladder and bile duct. It also forms the gastric glands, intestinal glands and pancreatic lobules (present in the pancreas) where it has secretory role and is called **glandular epithelium**.

Function. Protection, secretion and absorption.

4. Simple Ciliated Epithelium

Structure. The cells bear numerous delicate hair like outgrowths, the **cilia**, arising from **basal granules**. Mucus secreting goblet cells also occur in the ciliated epithelium. The cilia remain in rhythmic motion and create a current to transport the materials which come in contact with them. The ciliated epithelium is of two types.

(i) **Ciliated Columnar Epithelium**. It comprises columnar cells which have cilia on the free surface. This epithelium lines most of the respiratory tract and Fallopian tubes (oviducts). It also lines the ventricles of the brain and the central canal of the spinal cord. It is also present in tympanic cavity of middle ear and auditory tube (Eustachian tube).

(ii) **Ciliated Cuboidal Epithelium**. It consists of cubical cells which have cilia on the free surface. It occurs in certain parts of nephrons of the kidneys.

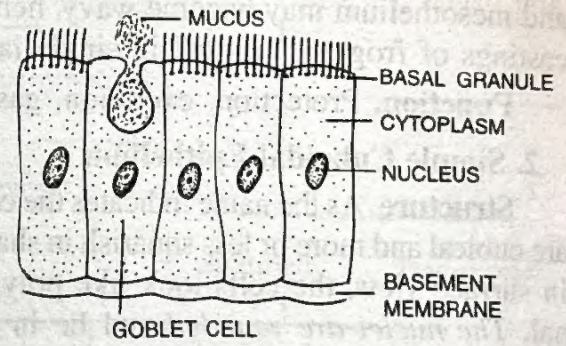


Fig. 7.9. Ciliated Columnar epithelium.

Functions of ciliated epithelium. The main function of ciliary movement is to maintain a flow of mucus or liquid or suspended particles or bodies constantly in one direction. In the respiratory tract the cilia help to push mucus towards the pharynx (throat). In the oviducts the cilia help to move an egg towards the uterus. The cilia of the ventricles (cavities) of the brain and central canal of the spinal cord help to maintain the circulation of cerebrospinal fluid present there. In the nephrons of the kidneys, cilia keep the urine moving.

5. Pseudo-stratified Epithelium

Structure. The cells are columnar, but unequal in size. The **long cells** extend up to free surface. The **short cells** *do not reach the outer free surface. The long cells have oval nuclei, however, short cells have rounded nuclei.* Mucus secreting goblet cells also occur in this epithelium. Although epithelium is one cell thick, yet it appears to be multi-layered which is due

to the fact that the nuclei lie at different levels in different cells. Hence, it is called pseudostratified epithelium. It is of two types :

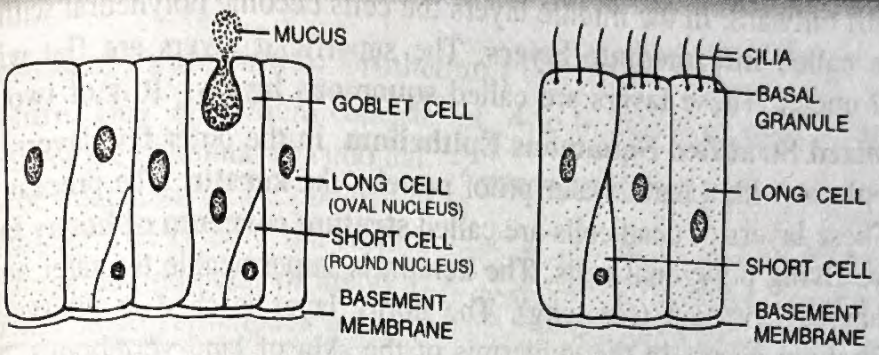


Fig. 7.10. Pseudostratified epithelium. A, Columnar. B, Columnar ciliated.

(i) **Pseudostratified Columnar Epithelium**. It consists of columnar cells. It occurs in the large ducts of certain glands such as parotid salivary glands and the urethra of the human male. It is also present in the olfactory mucosa.

(ii) **Pseudostratified Columnar Ciliated Epithelium**. It consists of columnar cells. The long cells have cilia at their free surface, however, the short cells are without cilia. This epithelium occurs in the trachea and large bronchi. The movements of the cilia propel the mucus and foreign particles towards the larynx.

Functions of Pseudostratified Epithelium. Protection, secretion, movement of secretions from glands, urine and semen in the male urethra and mucus loaded with dust particles and bacteria from the trachea towards the larynx.

Differences between Cilia, Stereocilia and Microvilli

Cilia (kinocilia)	*Stereocilia*	*Microvilli*
1. Cilia arise from the basal granules.	1. Basal granules are absent.	1. Basal granules are absent.
2. Motile.	2. Non motile.	2. Non motile.
3. They taper distally.	3. They are cylindrical.	3. They are extremely thin and short structures.
4. Not covered by glycocalyx.	4. May be covered by a coat of glycocalyx.	4. Not covered by glycocalyx.
5. A cilium has 9+2 ultra-structure.	5. Absent.	5. Absent.
6. Cilia occur in the cells of respiratory and reproductive tracts.	6. Stereocilia are found in some parts of the male reproductive tract such as the epididymis and vas deferens.	6. Microvilli are found in locations where absorption and secretion are the major activities of the cell (*e.g.*, intestine).

B. Compound Epithelia (Multilayered Epithelia)

These are made up of more than one layer of cells. The compound epithelia may be stratified and transitional.

1. Stratified Epithelium

It has many layers of epithelial cells, however, the deepest layer is made up of columnar or cuboidal cells. This epithelium is classified on the basis of the shape of the cells present in the superficial layers. It is of four types.

(i) **Stratified Squamous Epithelium**. The cells in the deepest (= basal) layer are columnar or cuboidal with oval nuclei. It is called **germinative layer** (= **stratum germinativum or stratum Malpighi**). The cells of this layer divide by mitosis to form new cells. The new cells gradually shift outward. In the middle layers the cells become polyhedral with rounded nuclei. These are called **intermediate layers**. The superficial layers are flat with transversely elongated nuclei. These layers are called **squamous layers**. It is of two types :

(a) **Keratinized Stratified Squamous Epithelium**. In the outer few layers, the cells replace their cytoplasm with a hard, water proof protein, the **keratin**. The process is called **keratinization**. These layers of dead cells are called **stratum corneum** or **horny layer**. The deeper layers have living polygonal cells. The keratin is impermeable to water and is also resistant to mechanical abrasion (scraping). The horny layer is shed at intervals due to friction. This epithelium occurs in the epidermis of the skin of land vertebrates.

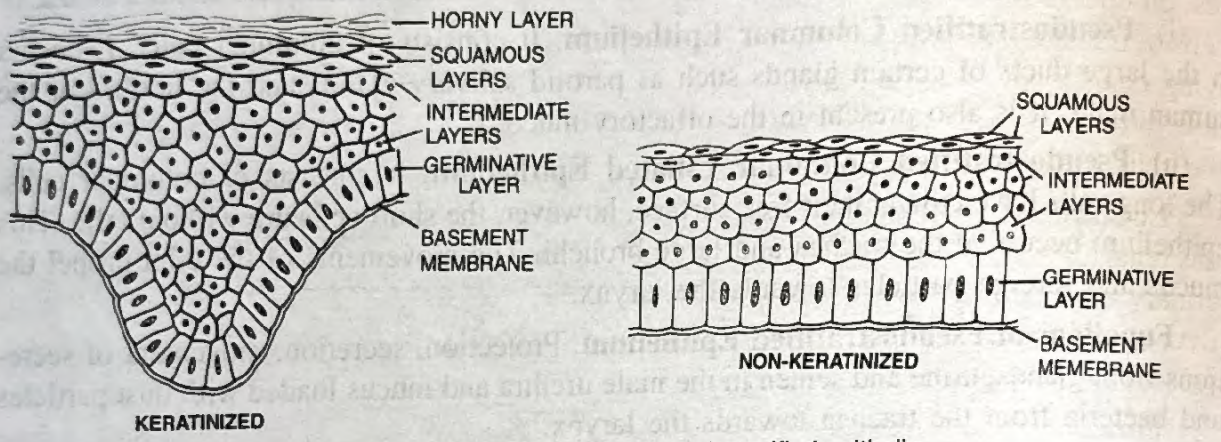


Fig. 7.11. Keratinised and Nonkeratinised stratified epithelium.

(b) **Nonkeratinized Stratified Squamous Epithelium.** As the name indicates, it does not have keratin. It is unable to check water loss and provides only moderate protection against abrasion (scraping). This epithelium occurs in the oral cavity (buccal cavity), tongue, pharynx, oesophagus, middle part of anal canal, lower parts of urethra, vocal cords, vagina, cervix (lower part of uterus), conjunctiva, inner surface of eye lids and cornea of eye.

Differences between Keratinized and Non-keratinized Stratified Squamous Epithelia

Keratinized Stratified Squamous Epithelium	*Non-keratinized Stratified Squamous Epithelium*
1. It forms epidermis of skin of land vertebrates.	1. It lines the buccal cavity, pharynx, oesophagus, etc
2. Keratin is present in the dead superficial cells.	2. Superficial cells are living and keratin is absent.
3. It is impermeable to water.	3. It is permeable to water.
4. It forms well protective covering against abrasions.	4. It forms moderately protective covering agains abrasions.

(ii) **Stratified Cuboidal Epithelium**. It has outer layer of cuboidal cells and basal layer of columnar cells. It forms the epidermis of fishes and many urodels (tailed amphibians such as salamanders). It also lines the sweat gland ducts and larger salivary and pancreatic ducts.

(iii) **Stratified Columnar Epithelium**. It has columnar cells in both superficial and basal layers. It covers the epiglottis and lines mammary gland ducts and parts of urethra.

(iv) **Stratified Ciliated Columnar Epithelium.** Its outer layer consists of ciliated columnar cells and basal layer of columnar cells. It lines the larynx and upper part of the soft palate.

2. Transitional Epithelium (= Urothelium; Fig. 7.12)

Structure. This epithelium consists of 4 to 6 layers of cells. The cells of deepest (= basal) layer are columnar or cuboidal. The cells of middle layer are polyhedral or pear shaped. The cells of the surface layer are *large* and globular or umbrella shaped. *There is no germinative layer or basement membrane but shows mitosis.* The cells of inner most (= basal) layer rest on underlying connective tissue. The cells of transitional epithelium and underlying connective tissue are very stretchable. When this eipithelium is stretched all the cells become flattened.

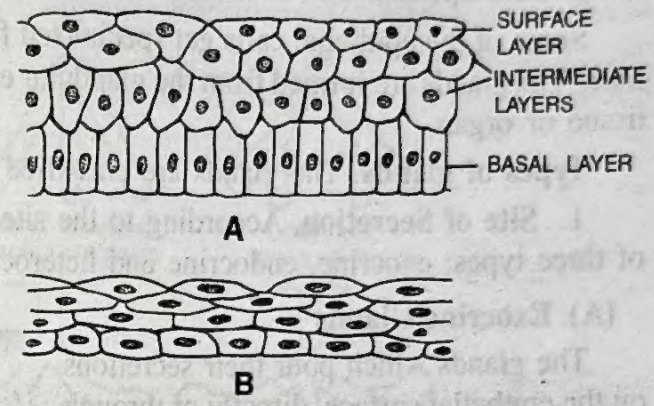


Fig. 7.12. Transitional epithelium. A, relaxed (= unstretched) ; B, stretched.

Location. This epithelium is found in the renal calyces, renal pelvis, ureters, urinary bladder and part of the urethra. Because of its distribution, transitional epithelium is also called **urothelium** (epithelium present in the urinary system).

Function. It permits distention. The transitional epithelium of the urinary bladder can be stretched considerably without being damaged. When stretched it appears to be thinner and the cells become flattened or rounded. Thus this epithelium is stretched or relaxed. It is also protective in function.

The cells of the basal layer of the transitional epithelium show occasional mitosis, but it is much less frequent than that of stratified squamous epithelium, as there is nomally little erosion of the surface.

Differences between Simple epithelium and Compound epithelium

Simple epithelium	*Compound epithelium*
1. It consists of a single layer of cells.	1. It consists of more than one layers of cells.
2. All the cells rest on the basement membrane.	2. Only cells of the deepest layer rest on the basement membrane. (It is absent in transitional epithelium).
3. It covers the moist surface where there is little wear and tear.	3. It covers the surface where constant wear and tear takes place.
4. It is secretory, absorptive, protective, etc.	4. It is mainly protective.

Differences Between Pseudostratified Epithelium and Transitional Epithelium

Pseudostratified Epithelium	*Transitional Epithelium*
1. It is a simple epithelium.	1. It is a compound epithelium.
2. It consists of long cells which extend upto free surface and short cells which donot reach the outer free surface.	2. It consists of basal, intermediate and surface cells.

3. It has basement membrane. 4. It may be ciliated or non-ciliated. 5. It is not capable of stretching. 6. It occurs in ducts of parotid salivary glands, parts of male urethra, trachea, large bronchi, etc.	3. It does not have basement membrane. 4. It is always non-ciliated. 5. It is capable of stretching. 6. It occurs in renal calyces, renal pelvis, ureters, urinary bladder and part of urethra.

Glandular Epithelium (Glands)

Some of the epithelial cells get specialised for secretion and are called glandular epithelium. The glands are formed from the glandular epithelium. A gland may be made up of a cell, tissue or organ.

Types of glands. The glands are classified in different ways :–

1. **Site of Secretion**. According to the site where secretion is released, the glands are of three types: exocrine, endocrine and heterocrine.

(A) Exocrine Glands

The glands which pour their secretions on the epithelial surface, directly or through ducts are called **exocrine glands** (= externally secreting glands). These include salivary glands, gastric glands, intestinal glands, tear glands, sweat glands, oil glands, mammary glands, etc.

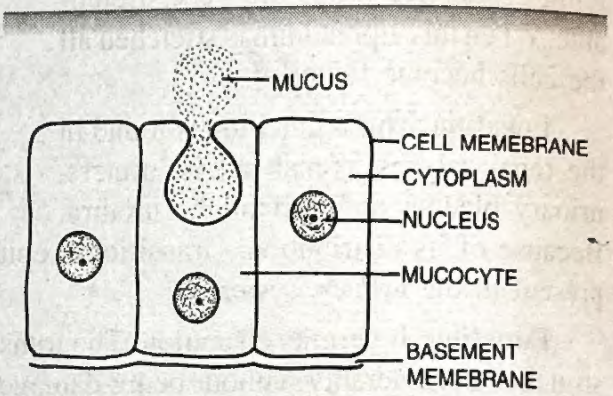


Fig. 7.13. Unicellular mucous gland (= Mucocyte).

The exocrine glands may be **unicellular** or **multicellular**. When unicellular glands secrete mucus, they are called **mucous cells** (= goblet cells or mucocytes). Mucus is a proteinaceous viscous and slimy substance. The mucous cells are common in the columnar epithelium of the intestine. When unicellular glands secrete a clear watery fluid, they are called **serous cells** (= serocytes). Serous cells are present in parotid salivary glands, intestinal glands and sweat glands. When the glands secrete both mucous and serous secretions, they are called mixed glands. There include pancreas, most gastric glands, sub mandibular salivary glands, etc.

A multicellular gland consists of a **duct** and **secretory portion**, both formed of epithelial cells. Multicellular glands are further of two types : tubular and saccular (= alveolar or acinous)

(i) **Tubular Glands**. The secretory portion is tube-like. They are of the following types.

(a) **Simple straight tubular glands**, *e.g.*, Crypts of Lieberkuhn (= a type of intestinal glands) in the human ileum and glands present in the male frog's nuptial pads.

(b) **Simple coiled tubular glands**, *e.g.*, sweat (= sudoriferous) glands of mammalian skin.

(c) **Simple branched tubular glands**, *e.g.*, Brunner's glands (= a type of intestinal glands) of human intestine, gastric glands, uterine glands and sweat glands of human armpits.

(d) **Compound tubular glands**, *e.g.*, milk glands of egg laying mammals, and salivary glands.

(ii) **Saccular glands** (= **Alveolar** or **Acinous** or **Acinar glands**). The secretory portions of these glands are flask shaped called **alveolus** or **acinus**. They are of the following types:

(a) **Simple saccular glands**, *e.g.*, cutaneous (mucous) glands of frog.

(b) **Simple branched saccular glands**, *e.g.*, oil (sebaceous) glands.

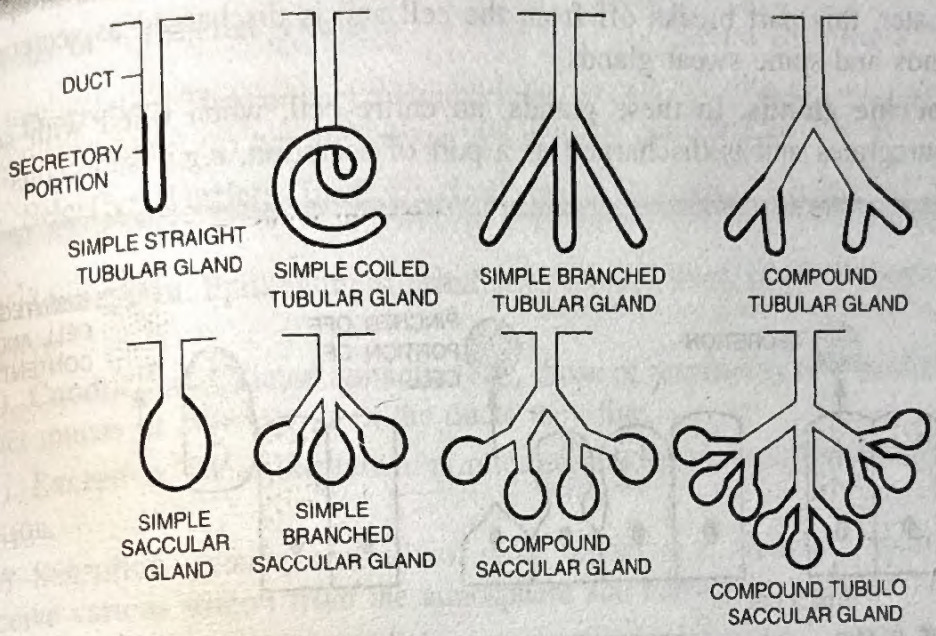


Fig. 7.14. Structural types of Exocrine glands.

(c) **Compound saccular glands**, *e.g.*, human milk glands, sublingual and sub mandibular salivary glands and exocrine part of pancreas.

(d) **Compound tubulo-saccular glands**. The secretory portion is both tubular and flask like, *e.g.*, pancreas, functional mammary glands, Cowper's glands in males and Bartholin's glands in females.

Differences between Simple Glands and Compound Glands

Simple Glands	*Compound Glands*
1. The duct of a simple gland is unbranched. 2. Secretory portion of a simple gland may be branched or unbranched. **Examples.** Sweat glands of mammalian skin, intestinal glands and oil glands.	1. The duct of a compound gland is branched. 2. Secretory portion of a compound gland is usually branched. **Examples.** Milk glands, salivary glands and pancreas.

(B) Endocrine Glands (= Ductless Glands)

They lack ducts. Their secretions are called **hormones** which are poured directly into the blood and lymph. The blood and lymph carry hormones to the target organs. Examples of endocrine glands are thyroid, parathyroids, hypothalamus, pituitary, adrenals, thymus, etc.

(C) Heterocrine Glands

They have both exocrine part and endocrine part. The former sends its secretion by way of a duct and the latter releases its secretion directly into the blood and lymph. Pancreas and gonads (testes and ovaries) are heterocrine glands.

2. **Mode of Secretion.** On the basis of the mode of releasing the secretion, the glands are of three types: merocrine, apocrine and holocrine.

(i) **Merocrine glands.** In these glands, the secretion is discharged by the cells by simple diffusion, so that there is no loss of cells or their parts, *e.g.*, goblet cells, most sweat glands, salivary glands, intestinal glands.

(ii) **Apocrine glands***. In these glands, secretory products accumulate in apical part of the cells. Later, this part breaks off from the cell and is discharged as secretion, e.g., mammary glands and some sweat glands.

(iii) **Holocrine glands.** In these glands, an entire cell, when filled with secretory products, distintegrates and is discharged as a part of secretion, *e.g.*, sebaceous glands.

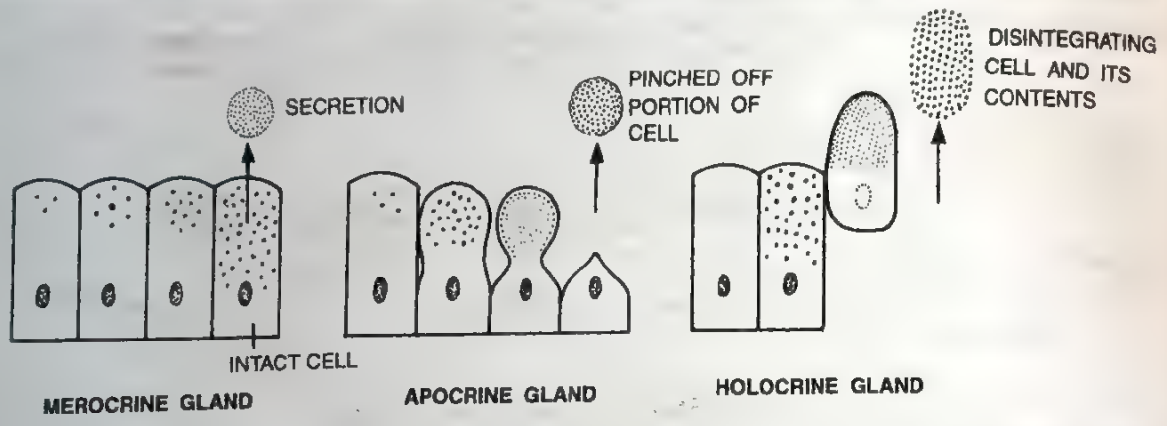


Fig. 7.15. Types of glands according to their modes of secretion.

Sometimes holocrine glands are described as those endocrine glands which secrete only hormones, *e.g.*, thyroid, parathyroids, adrenals, pituitary and hypothalamus.

- **Zymogen granules** appear in the cytoplasm of the secretory cell.

Modified Epithelia. Six more epithelia need a brief mention :

(i) **Sensory Epithelium** (= **Neurosensory epithelium** or **Neuroepithelium**). This epithelium consists of columnar **sensory cells** and **supporting cells**. The sensory cells bear **sensory hairs** at their free ends and nerve fibres at their other ends. The supporting cells are without sensory hairs and nerve fibres. Sensory epithelium is present in the nasal chamber, tongue, retina of eye and internal ear. Olfactory mucosa (present in the nasal chamber) is also called **Schneiderian membrane**. The olfactory receptors are modified neurons.

(ii) **Myoepithelium**. Its cells are called **myoepitheliocytes** which contain actin and myosin filaments and are capable of contraction. It serves to expel secretions, such as sweat, milk and saliva from the sweat, mammary and salivary glands respectively. Myoepithelium arises from the ectoderm.

(iii) **Pigmented Epithelium**. The cells of this epithelium contain pigment hence it is called pigmented epithelium. It is present in the external layer of the retina and posterior part of the iris of the eye.

(iv) **Germinal Epithelium.** It consists of cuboidal cells. It is present in the ovaries and testes. Its cells produce gametes (ova and sperms) for sexual reproduction.

(v) **Glandular Epithelium.** It consists of polygonal, columnar or cuboidal cells. It is

*This concept is outdated.

present in glands such as gastric glands, intestinal glands, etc. and secretes fluid. Glandular epithelium has been described separately.

(vi) **Absorptive Epithelium.** The cells of this epithelium may be columnar or cuboidal and have microvilli on their free surface. It is found in the stomach, intestine and nephrons of kidneys. It helps in the absorption of food in stomach and intestine and liquid material in the nephrons.

Functions of Epithelial Tissues

(i) **Protection.** They protect the underlying tissues from (a) mechanical injury (b) entry of germs (infection) (c) harmful chemicals and (d) drying up.

(ii) **Selective Barriers.** Epithelia check the absorption of harmful or unnecessary materials.

(iii) **Absorption.** Epithelium of uriniferous tubules (nephrons), stomach and intestine is absorptive.

(iv) **Conduction.** Ciliated epithelia (*e.g.*, those of respiratory and genital tracts) serve to conduct mucus or other fluids in the ducts they line.

(v) **Excretion.** The epithelium of uriniferous tubules is specialized for urine formation for excretion.

(vi) **Sensation.** Sensory epithelia of sense organs (*e.g.*, olfactory epithelium, etc.) help to receive various stimuli from the atmosphere and convey them to the brain.

(vii) **Regeneration.** When epithelia are injured, they regenerate more rapidly than other tissues, and thus facilitate rapid healing of wounds.

(viii) **Respiration.** Epithelium of alveoli of the lungs brings about exchange of gases between blood and air.

(ix) **Pigmentation.** Pigmented epithelium of the retina darkens the cavity of eyeball.

(x) **Secretion.** Epithelium also forms glands that secrete secretions such as mucus, gastric juice and intestinal juice.

(xi) **Reproduction.** Germinal epithelium of the ovaries and seminiferous tubules of the testes produce ova and sperms respectively.

(xii) **Exoskeleton.** Epithelium also produces exoskeletal structures such as scales, feathers, hair, nails, claws, horns and hoofs.

II. CONNECTIVE TISSUES

Connective tissue is the most abundant and widely distributed tissue of the body. It connects different tissues or organs and provides support to various structures of animal body.

Origin. Connective tissues are formed by the **mesoderm** of the embryo.

Basic Components of Connective tissues. Three components are present in the connective tissues. These are matrix, cells and fibres.

(i) **Matrix** (ground substance). It is mainly a mixture of carbohydrates and proteins. These have been identified as various forms of mucopolysaccharides. The most common mucopolysaccharide ground substance is **hyaluronic acid**.

(ii) **Connective Tissue cells.** The cells are of different types (a) **Fibroblasts** produce fibres and matrix. (b) **Adipose cells** (= Adipocytes or Lipocytes) store fat. (c) **Plasma cells**

(= Plasmatocytes) synthesize antibodies. Plasma cells are also called **'Cart Wheel Cells'** because thin chromatin in the nucleus forms four or five clumps giving the nucleus a resemblance to a cart wheel. (d) **Mast cells** (= Mastocytes) produce histamine, heparin and serotonin. Mast cells are related to **basophils** of the blood. **Histamine** dilates the walls of blood vessels in inflammatory and allergic reactions while **heparin** checks clotting of blood (anticoagulant) inside the blood vessels. **Serotonin** acts as a vasoconstrictor to arrest bleeding and to increase blood pressure. (e) **Macrophages** (= Histocytes or Clasmatocytes) ingest cell debris, bacteria and foreign matter. Macrophages are derived from monocytes. (f) **Lymphocytes** ingest cell debris, bacteria and foreign matter. (g) **Mesenchyme cells** give rise to various types of connective tissue cells. (h) **Chromatophores** (Pigment cells) are found in the dermis of the skin where they impart colour to the animal. (i) **Reticular cells**. They form reticular tissue and are phagocytic in nature.

Monocytes, eosinophils and **neutrophils** may be present in the connective tissue. Lymphocytes, monocytes, eosinophils, basophils and neutrophils are WBCs and are to be described in detail in the blood.

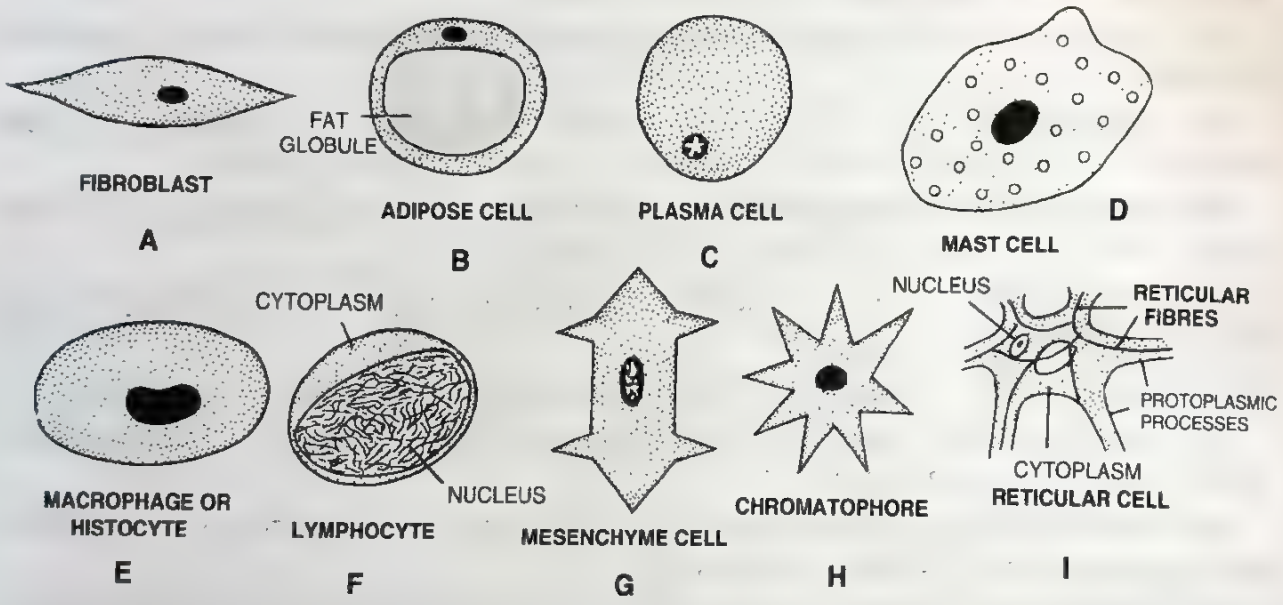


Fig. 7.16. Different types of cells in the connective tissues.

(iii) **Connective Tissue Fibres.** These are of three types: (a) **Collagenous or collagen fibres** (white fibres) are made up of **collagen** protein. When boiled in water collagen changes into gelatin. These fibres occur in bundles and are unbranched and inelastic. (b) **Elastic fibres** (yellow fibres) are formed of a protein called **elastin**. These fibres are branched and elastic. (c) **Reticular fibres**. These fibres are delicate, branched and inelastic. They are made up of **reticulin** protein. They always form a net work.

Differences between the fibres of connective tissue

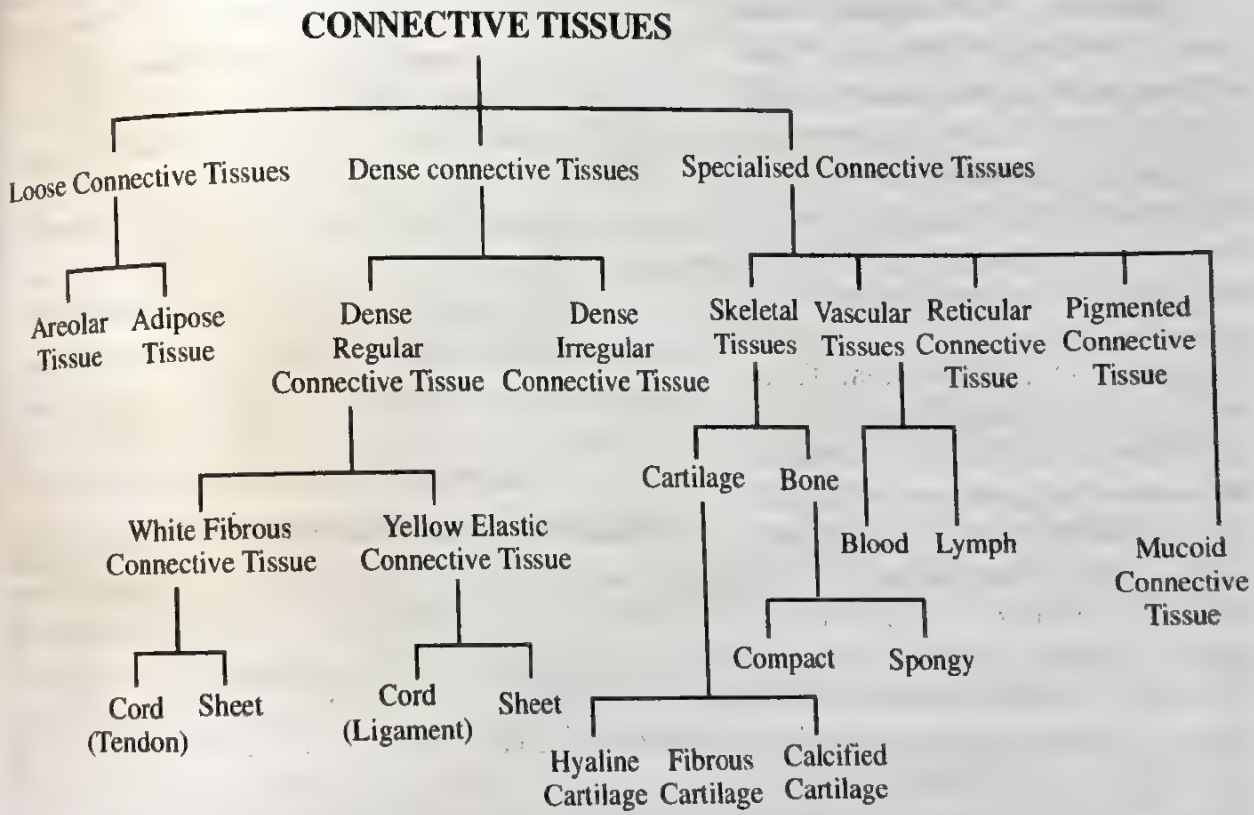
Nature	*Collagen fibres (White fibres)*	*Elastic fibres (Yellow fibres)*	*Reticular fibres*
1. Location	Most abundant in tendons.	Most abundant in ligaments.	Most abundant in spleen, lymph nodes and bone marrow.
2. Occurrence	Occur in bundles.	Singly	Singly
3. Colour	Glistening white.	Yellow	White

4. Nature	Unbranched, thick, long and wavy.	Branched, thin, long and straight.	Branched and form net work, short.
5. Protein	Collagen	Elastin	Reticulin
6. Elasticity	Tough and nonelastic	Elastic	Delicate

Characteristic Features of Connective Tissues. The connective tissue consists of living cells and extra-cellular matrix. The extra cellular matrix has nearly amorphous ground substance which is made of glycoproteins with associated mucopolysaccharides. Ground substance of extra cellular may be liquid, gel or solid. Connective tissues connect and provide support to various structures. They develop from embryonic mesoderm.

Types of Connective Tissues

The connective tissues can be classified into three types (i) Loose connective tissues (ii) Dense connective tissues and (iii) Specialised connective tissues.



I. Loose Connective Tissue

(A) Areolar Tissue (= Loose connective tissue). This tissue is most widely distributed connective tissue in the animal body.

Structure. It is named so because it takes the form of fine threads crossing each other in every direction leaving small spaces called **areolae**. Thc areolar tissue consists of ground substance, the **matrix, white, yellow** and **reticular fibres** and cells like **fibroblasts, mast cells, macrophages** (= histocytes or clasmato-cytes), **lymphocytes, plasma cells, mesenchyme cells, chromatophores. Fat cells** can be seen in small groups. Description of matrix, fibres and cells has already been given in the general structure of connective tissue.

Location. As stated earlier, the areolar tissue is the most widely distributed connective tissue in the body. It is present under the skin as subcutaneous tissue in between and around muscles, nerves and blood vessels in submucosa of gastro-intestinal tract and respiratory tract, in the bone marrow, between the lobes and lobules of compound glands and in

mesenteries and omenta. It also forms the internal frame work (= stroma) of many solid organs. In fact it forms packing nearly in all organs.

Functions. To bind parts together is the primary function of areolar tissue. Other functions are to provide strength, elasticity, support to the parts where this tissue is present. It also provides rapid diffusion of materials and migration of wandering cells towards areas of infection and repair.

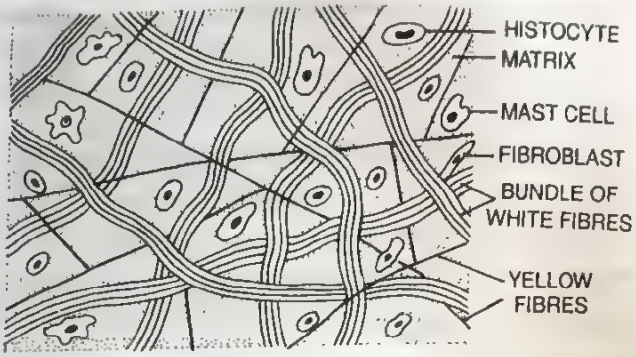


Fig. 7.17. Areolar tissue

(B) Adipose Tissue. It is a fat storing connective tissue.

Structure. The adipose tissue consists of several spherical or oval **adipose cells** (= adipocytes or fat cells ; Fig. 7.18). Each adipose cell contains **fat globules**, due to which the nucleus and the cytoplasm are displaced to the periphery. These cells are often called **signet ring cells** because they resemble a signet ring when seen in cross section. There are two types of adipose tissue : white (or yellow) fat and brown fat. **White fat** contains large adipose cells, each having a single large fat globule and hence, called **monolocular**. The cytoplasm in these cells is pushed to a peripheral layer containing nucleus. The adipose cells of **brown fat** are **multilocular**, each cell with several small fat globules. Brown colour is due to iron containing cytochrome pigment in fat. Brown fat found in those mammals which have an oxidation power 20 times more than that of yellow fat because brown fat cells are loaded with a large number of mitochondria. Brown fat is found in hibernating mammals such as rats and other rodents and in new-born human babies. The fibres are few in number and form a loose network for supporting the fat-laden cells. If these cells are treated with alcohol, the fatty substance is dissolved and the cells become vacuolated.

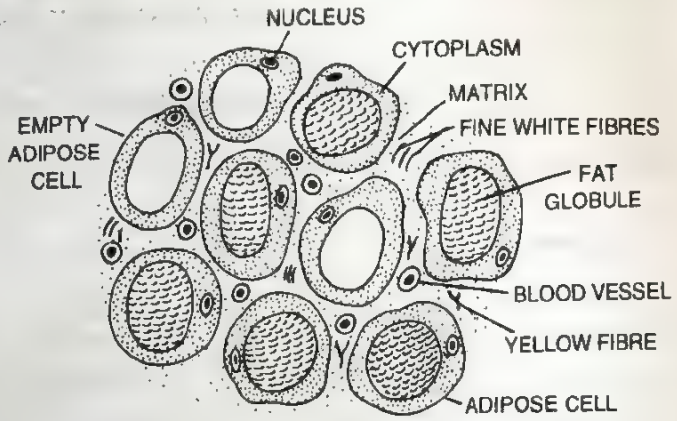


Fig. 7.18. Adipose tissue.

Location. The adipose tissues are found in the subcutaneous tissue, around the heart, kidneys, eyeballs, mesenteries and omenta, where fat is stored. Adipose tissue is also found in the **blubber** of whales and elephants, **hump** of camal, **fat bodies** of frog and yellow bone marrow.

Functions. The adipose tissue is chiefly a **food reserve** or **'fat depot'** for storage. The sub cutaneous fat prevents heat loss from the body and also rounds off the body contour. It forms a shock-absorbing cushion around the eye balls and kidneys. It also provides support and protection. This tissue also helps in the production of blood corpuscles. We become fatty when our body cells accumulate fat globules. Excessive accumulation of fat is called **adiposis**.

II. Dense Connective Tissue

It is of two types : dense regular connective tissue and dense irregular connective tissue.

(A) **Dense Regular Connective Tissue.** In the dense regular connective tissue, the collagen fibres are present in rows between many parallel bundles of fibres. It is also of two types: white fibrous connective tissue and yellow elastic connective tissue.

1. White fibrous connective tissue. It consists of mainly white (collagen) fibres which are arranged in bundles. The fibroblasts are present in rows between the bundles.

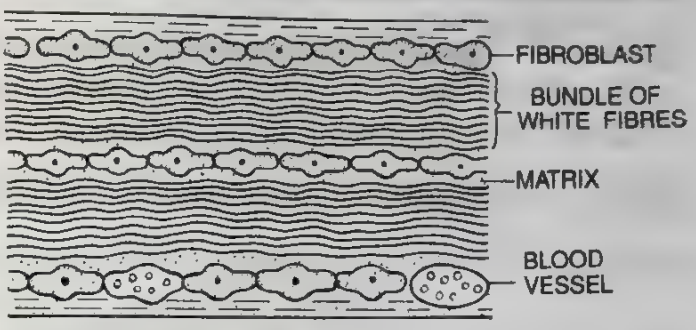


Fig. 7.19. White fibrous connective tissue.

(i) White Fibrous Cords (Tendons). The white fibrous connective tissue forms cords called **tendons** which connect the skeletal muscles with the bones.

(ii) White Fibrous Sheets. White fibrous connective tissue also forms flat plates or sheets. It occurs in the dermis of the skin, connective tissue sheaths of muscles and nerves and tunica adventitia (= outer coat) of large blood vessel, periosteum of the bone, perichondrium of the cartilage, pericardium of the heart, duramater of the brain and spinal cord, renal capsule of the kidney, sclera and cornea of the eye ball and fibrous capsules of penis and testes and between skull bones.

White fibrous connective tissue has great strength, however, its flexibility is limited. The presence of white fibrous tissue at the joints between skull bones makes them immovable. Due to presence of abundant white fibres, the skin dermis of large mammals yields **leather** after chemical treatment called **tanning**.

2. Yellow elastic connective tissue. This tissue is mainly made up of much thicker branched loose network of yellow fibres. The white fibres also occur but they are very fine. The fibroblasts are irregularly scattered. It also contains mast cells, macrophages and often some adipose cells.

(i) Yellow Fibrous Cords (Ligaments). The yellow elastic connective tissue form cords called **ligaments** which join bones to bones.

(ii) Yellow Fibrous Sheets. The sheets formed by this tissue occur in the walls of blood vessels, lungs, bronchioles, true vocal cords, cartilage of larynx, trachea, capsules of spleen and **ligamenta flava** which connect adjacent vertebrae.

Yellow Elastic Connective tissue has considerable strength and remarkable elasticity. Thus it allows stretching of various organs.

Many years old **'mummies'** still have their arteries intact due to well preserved elastic fibres.

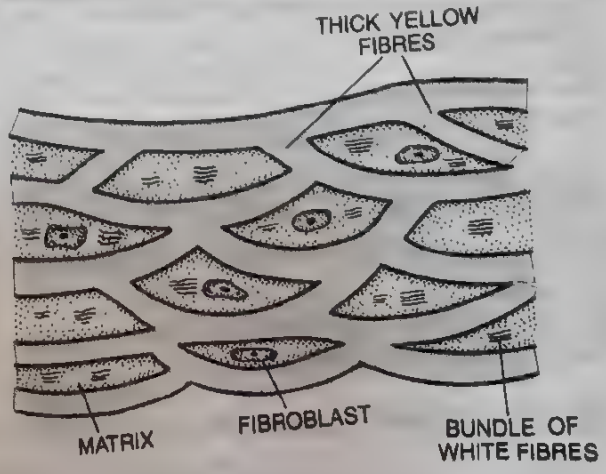


Fig. 7.20. Yellow elastic connective tissue.

• **Sprain** is caused by excessive pulling (stretching) of ligaments.

Differences between Tendon and Ligament

Tendon	*Ligament*
1. It is made up of white fibrous tissue.	1. It is made up of yellow elastic tissue with some collagen fibres.
2. Fibroblasts lie in almost continuous rows.	2. Fibroblasts lie scattered.
3. Tendon connects a skeletal muscle to a bone.	3. Ligament connects a bone to another bone.
4. It is tough and inelastic.	4. It is strong but elastic.

(B) Dense Irregular Connective Tissue. It has fibroblasts and many fibres (mostly collagen) that are oriented differently. This tissue is present in the skin.

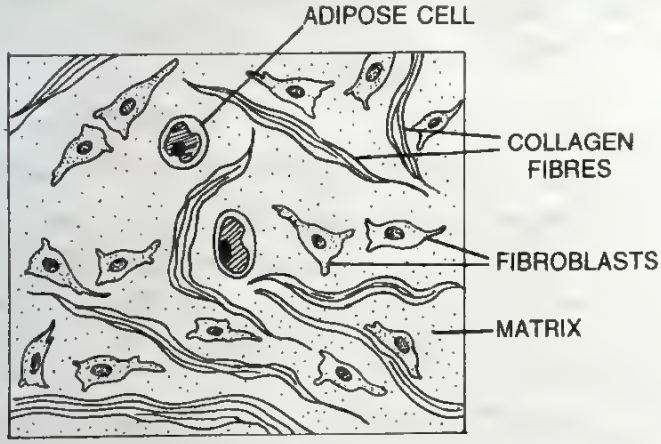


Fig. 7.21. Dense Irregular connective tissue.

Differences between Dense Regular Connective Tissue and Dense Irregular Connective Tissue

Dense Regular Connective Tissue	*Dense Irregular Connective Tissue*
1. In this tissue, the collagen fibres are present in rows between many parallel bundles of fibres.	1. This tissue has fibroblasts and many fibres (mostly collagen) that are oriented differently.
2. Fibroblasts occur in good number.	2. Fibroblasts are fewer.
3. Tendons and ligaments are examples of this tissue.	3. This tissue is present in the skin.

Difference between Loose Connective Tissue and Dense Connective Tissue

Loose Connective Tissue	*Dense Connective Tissue*
1. The cells and fibres are loosely arranged in the matrix.	1. The cells and fibres are compactly arranged in the matrix.
2. **Examples.** Areolar tissue and Adipose tissue.	2. **Examples.** Tendons and Ligaments.

III. Specialised Connective Tissues

These are of the following types.

(A) Skeletal Tissues. These connective tissues form the endoskeleton of the verte-

brates. Hard parts of the body constitute skeleton. These support the body, protect the various organs and help in locomotion. Skeletal tissues include **cartilage** and **bone**.

1. Cartilage (= Gristle). Cartilage is a soft skeletal tissue. It is not rigid like bone. It is found more abundantly in vertebrate embryoes because most of the bones forming skeleton of the adult are cartilaginous in the early stage. However it is commonly found in the body of adult vertebrates.

Structure of Cartilage. A typical (generalized) cartilage consists of the following parts:

(i) **Cartilage Cells.** A cartilage cell is present in a fluid filled space, the **cartilage lacuna** (pl. **lacunae**), which affects the shape of the cell. Young cartilage cells are relatively small, often flattened with many small surface projections (filopodia) and are called **chondroblasts** (this term is also used for embryonic cartilage producing cells). Mature cells are larger in size (these cells increase in size with age), more rounded, but still have a few surface projections and are known as **chondrocytes**. The chondroblasts are metabolically more active cells than chondrocytes.

(ii) **Ground Substance (= Matrix).** It consists essentially of water, **proteoglycans** (proteins and carbohydrates), some lipid, collagen, noncollagenous protein, and collagen fibres. The core protein (mucoprotein) is **aggrecan**. The carbohydrates are chemically **glycosaminoglycans** (GAG). They include chondroitin sulphate, keratin sulphate and hyaluronic acid. Keratin sulphate increases with maturity. These molecules form a firm gel that gives firm consistency to the ground substance of the cartilage.

A gelatin-like substance obtained from cartilage by boiling is called **chondrin**.

The free surfaces of hyaline cartilage (to be described ahead) are covered by a fibrous membrane called the **perichondrium** but it is not present in fibrous cartilage. The perichondrium contains blood vessels.

Cartilage is usually described as an avascular (without blood supply) tissue but it is not true. There are present **cartilage canals**, through which blood vessels may enter cartilage. Cartilage cells receive their nutrition by diffusion from blood vessels in the perichondrium or in cartilage canals. Cartilage canals may play a role in the ossification (formation of bones) of cartilage by carrying bone forming cells.

The growth of the cartilage is always from the periphery (**unidirectional**).

Types of Cartilages. The cartilages are of three types :

(a) **Hyaline Cartilage** (*hyalos = glass*; Fig. 7.22). It contains clear, large amount of translucent, slightly elastic matrix with less fibres. The matrix often has very fine white fibres which are difficult to observe. It is most prevalent cartilage. It forms articular surfaces at the joints of long bones, where it is called **articular cartilage**. It forms rings of trachea and bronchi, sternal parts of ribs (= **costal cartilages**), hyoid apparatus, nasal septum and also part of larynx. Most of the embryonic skeleton consists of hyaline cartilage.

Hyaline cartilage forms the skeleton of elasmobranch fishes (cartilaginous fishes) and the embryonic skeleton in bony vertebrates.

(b) **Fibrous Cartilage.** It has well developed fibres in the matrix. It is of two types : White fibrous cartilage and yellow elastic fibrocartilage.

(i) **White Fibrous Cartilage** or **White Fibrocartilage**. The matrix is firm and has abundant white fibres. It occurs in the intervertebral discs where it acts as cushion and in the pubic symphysis (region between the two pubic bones of the pelvic girdle) where it helps in parturition (process of birth). White fibrous cartilage is the **strongest** cartilage (Fig. 7.23)

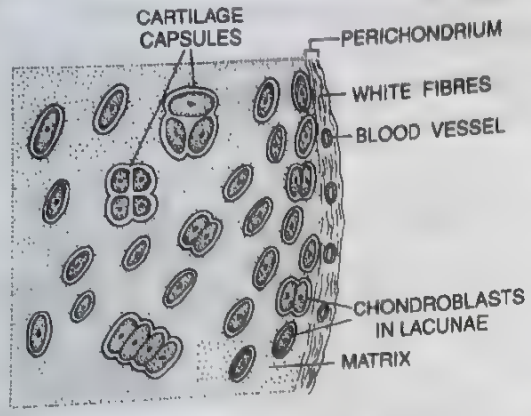


Fig. 7.22. Hyaline cartilage.

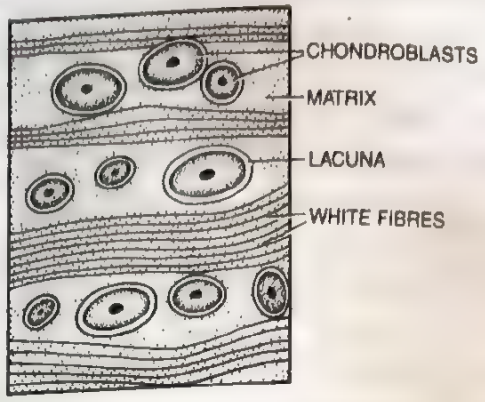


Fig. 7.23. White fibrous cartilage

(ii) **Yellow Elastic Fibrocartilage** (Fig. 7.24). The matrix contains numerous yellow fibres which form a network by uniting with one another. Due to the presence of yellow fibres, the cartilage becomes more flexible. This type of cartilage is found in the pinna and external auditory canal of the ear, Eustachian tubes, epiglottis and tip of the nose. It makes these organs flexible.

(c) **Calcified Cartilage.** Sometimes matrix contains granules of calcium carbonate, then the cartilage is called calcified cartilage. Calcium carbonate makes the cartilage hard and inelastic. This cartilage is found in suprascapula of pectoral girdle of frog and vertebrae of shark.

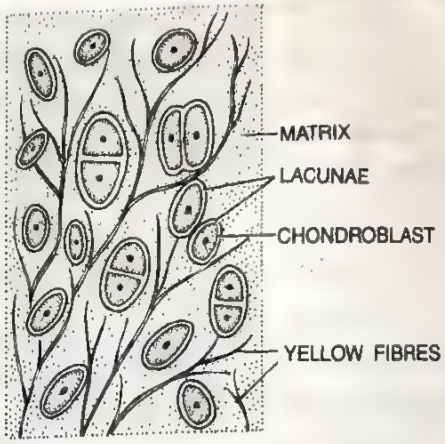


Fig. 7.24. Yellow elastic fibrocartilage.

Differences between different types of Cartilages

	Hyaline cartilage	*White fibrous cartilage*	*Elastic cartilage*	*Calcified cartilage*
1. Location	In the articular cartilages of long bones, sternum, ribs, nasal cartilages, larynx, trachea and hyoid apparatus.	In the intervertebral discs and pubic symphysis.	In the pinna, external auditory canal, Eustachian tubes, epiglottis, tip of the nose.	In the supra scapula of pectoral girdle of frog and vertebrae of shark.
2. Colour	Bluish white	Glistening white	Yellowish	White
3. Appearance	Shiny or translucent	Opaque	Opaque	Opaque
4. Fibres	Either absent or very thin and few.	Numerous white fibres.	Numerous yellow fibres.	No fibres, calcium salts
5. Elasticity	Flexible	More firm	Most flexible	Hard & nonelastic

2. **Bone.** Bone is the **hardest tissue** in the body and supports various organs. The matrix is tough containing both inorganic and organic substances. The inorganic salts present in the matrix are calcium phosphate, calcium carbonate, calcium fluoride, magnesium phosphate, etc. If a bone is **dried**, its organic matter (living matter) is destroyed and inorganic

part is left behind. On the other hand if a bone is kept in a dilute HCl for some time, its inorganic part is dissolved and organic part is left behind. Such a bone is called **decalcified bone**. Study of a dried bone shows its inorganic matter, while that of a decalcified bone reveals the animal matter. Thus bone may be studied in two forms: decalcified and dried.

Microscopic Structure of Decalcified Mammalian Bone

It consists of four parts : periosteum, matrix, endosteum and bone marrow.

(a) **Periosteum.** It is a thick and tough sheath that forms an envelop around the bone. It is composed of collagen (= white) fibrous tissue. Bundles of periosteal collagen fibres, called **Sharpey's fibres**, penetrate the bone matrix to provide a firm connection between the two. The periosteum contains blood vessels. The periosteum also contains bone-forming cells, the **osteoblasts** which produce new bone material.

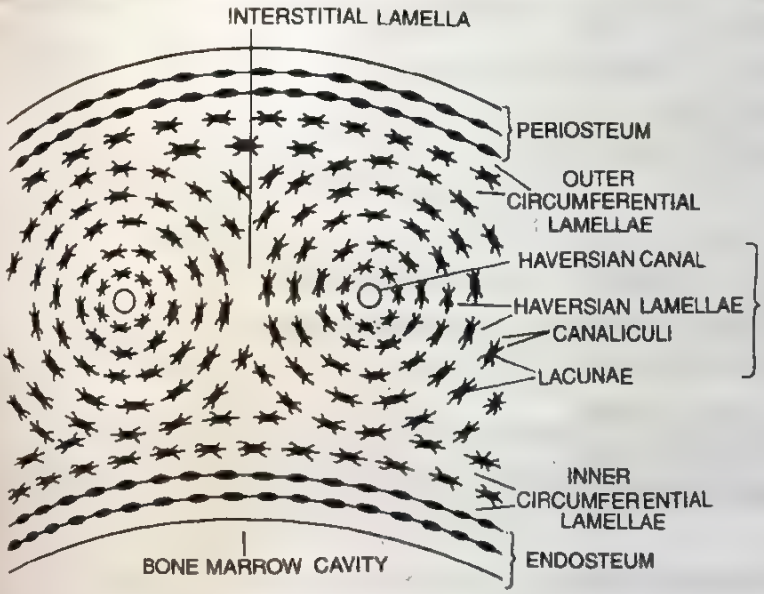


Fig. 7.25. T.S. Dried Mammalian bone.

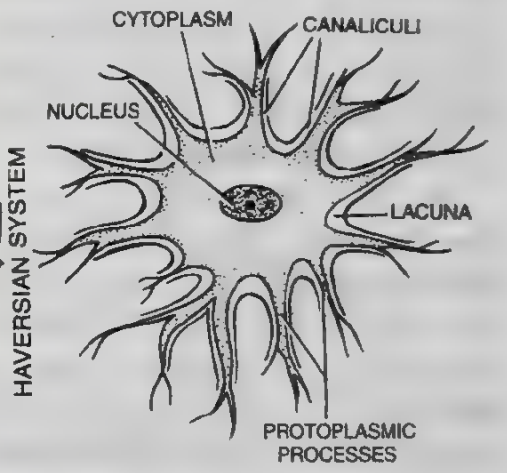


Fig. 7.26. An osteocyte.

(b) **Matrix.** It is composed of a protein called **ossein**. The main salts found in the matrix are calcium phosphate, calcium carbonate, sodium chloride and magnesium phosphate. Of these *calcium phosphate is maximum in the vertebrate bone*. The **Haversian canals**, *a characteristic feature of the mammalian bones*, are present in the matrix. Each Haversian canal contains an artery, a vein, a lymph vessel, a nerve and some bone cells, all packed in with connective tissue. The Haversian canals are interconnected by transverse channels, the **Volkmann's canals**.

The matrix has numerous inactive bone cells, the **osteocytes**. The latter contain reduced numbers of cell organelles and often store glycogen. An osteocyte is surrounded by

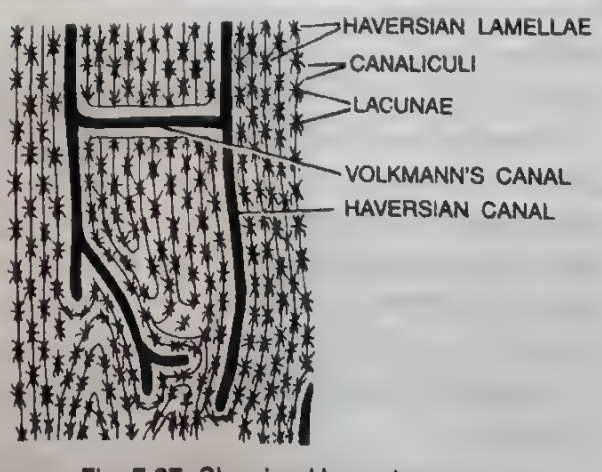


Fig. 7.27. Showing Haversian canals and Volkmann's canal.

a fluid-filled space, the **bone lacuna**, which leads into fine radiating channels, the **canaliculi**. In the developing bone, the osteocytes give off several projections called **protoplasmic processes** (= **filopodia**) which extend through the canaliculi. With the help of canaliculi and protoplasmic processes one osteocyte is in contact with another osteocyte.

The matrix of the bone occurs as layers called **lamellae**. The lamellae are of four types. (a) **Haversian lamellae**. These lamellae occur around the Haversian canals. A Haversian canal with its surrounding lamellae and osteocytes constitute a cylindrical unit of bone called **Haversian system** or **osteon.** *Haversian systems are absent in spongy bones of mammals.* (b) **Interstitial lamellae.** These lamellae occur between the Haversian systems. (c) **Outer circumferential lamellae** (= outer concentric lamellae). These lamellae occur inner to periosteum. (d) **Inner circumferential lamellae** (= **inner concentric lamellae**). These lamellae occur outer to endosteum.

(c) **Endosteum.** It is present outer to the bone marrow cavity. Like the periosteum, it comprises white fibrous tissue and osteoblasts (bone forming cells). But the white fibrous tissue is present here inner to osteoblasts. The long bone thus grows in thickness from two sides. This type of growth is called **bidirectional growth**.

(d) **Bone Marrow.** In long bones such as limb bones (humerus, femur, etc.) a cavity called **bone marrow cavity** is present inner to the endosteum. The bone marrow cavity is filled with a soft and semisolid fatty neurovascular tissue termed as **bone marrow.** In fact bone marrow is a special kind of tissue which is called **myelogenous** or **myeloid tissue**.

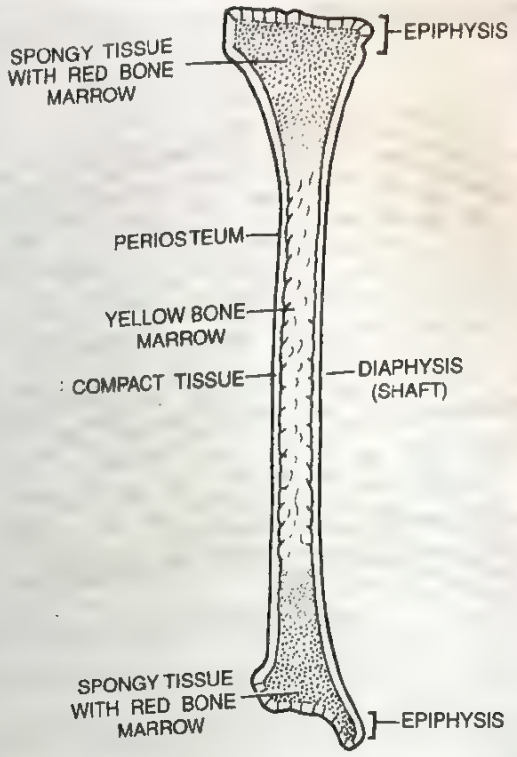


Fig. 7.28. L.S. of a complete long bone.

Types of Bone Marrow. It is of two types (a) **Red bone marrow.** It is red due to abundant blood vessels. It is present in the spongy parts of the bones (*e.g.*, **epiphyses**). It produces red blood corpuscles, white blood corpuscles (monocytes, eosinophils, basophils and neutrophils) and platelets. (b) **Yellow bone marrow.** It is present in the shafts of long bones. It is yellow in colour and has much fatty tissue. It produces blood corpuscles in emergency, *i.e.*, at the time of excessive loss of blood; when it changes into red bone marrow.

During foetal life and at birth there is red bone marrow throughout the skeleton. After about the fifth year the red bone marrow is gradually replaced in the long bones by yellow bone marrow. By 20 to 25 years the red bone marrow persists only in the vertebrae, sternum, ribs, clavicles, scapulae, pelvis, cranial bones and in the proximal ends of femora (pl. of femur) and humeri (pl. of humerus). In old age the bone marrow of the cranial bones undergo degeneration and is then called **gelatinous marrow**.

Types of Bone. On the basis of its texture, a bone is of two types : compact and spongy (cancellate).

(i) **Compact (Dense) Bone.** It is comparatively hard and compact. It is found in the shaft of long bones. It contains yellow bone marrow and has Haversian systems. (Detailed

microscopic structure of compact bone has already been discussed under the heading of microscopic structure of mammalian bone).

(ii) **Spongy (Cancellate) Bone.** It consists of a network of thin and irregularly longitudinal and tranverse bony bars called **trabeculae** covered by the endosteum. It is found at the enas of long bones (epiphyses). Spongy bone contains red bone marrow but it is without *Haversian systems.*

Differences between compact and spongy bones

	Compact bone	*Spongy bone*
1. Location	In the shaft (diaphysis) of long bones.	In the epiphyses of long bones.
2. Lamellae	Arranged to form Haversian system.	Arranged irregularly, so Haversian systems are not present. Lamellae form trabeculae.
3. Bone marrow	Yellow, stores fat	Red, produces RBCs
4. Bone marrow cavity	Narrow	Broad
5. Nature	Comparatively hard and compact	Spongy

Ossification (Bone formation). The skeleton is formed entirely of cartilage in an early embryo. Bone formation occurs later. The process of bone formation is called **ossification** (*os* = bone; *facio* = to make) or **osteogenesis.**

Bones are of the following types according to their source of formation.

1. **Cartilaginous or Replacing Bones.** These bones develop from the pre-existing cartilage and practically replace the cartilage. They are also called **endochondrial bones.** Examples: humerus, femur.

2. **Investing or Dermal or Membrane Bones.** These bones develop in the dermis of the skin as thin plates and sink to get attached over the original cartilaginous endoskeleton. In fact these bones become invested upon original cartilages hence their name. Examples: frontal, nasals, vomers and parietals of the skull.

3. **Sesamoid* Bones.** These bones are formed in the tendons at the joints. Example: patella (knee-cap).

4. **Visceral Bones.** These are formed in the soft organs (= viscera). Examples: **os cordis** in the heart of some ruminants (*e.g.,* deer), **os penis** in the penis of most bats, insectivores, rodents (*e.g.,* rats), carnivores (*e.g.,* dog, walrus), whales, some primates (not man), **os clitoris** in the clitoris of many carnivores, and **os palpebrae** in the eyelids of crocodiles. A small bone also develops in the crest of a bird and snout of a hog.

- **Osteoclasts.** These cells are derived from osteoblasts and osteocytes, rich in **acid phosphatase** and contain slightly basophilic cytoplasm and are lysosome-rich, multinucleate cells which destroy bone matrix. They are also called *bone destroying cells.* Thus the osteoclasts take part in the bone **resorption.**
- **Osteomyelitis.** Inflammation of the bone marrow and adjacent bone and epiphysial cartilage.
- **Paget's disease.** Irregular thickening and softening of bones, resulting in deformation of bones.
- A bone kept in KOH remains unaffected
- **Osteomyelodysplasia.** Enlargement of the bone marrow cavities, thinning of the osseous tissue, thinning of osseous tissue, large thin-walled vascular spaces, leukopenia (fall in WBC count) and irregular fever.
- A deficiency of vitamin D produces **Rickets** in children and **osteomalacia** in adults.

* Having the shape of seed. **os** = bone/opening, *itis* = inflammation.

When required, calcium and phosphate are released from the bone into the blood under the influence of the hormones, **parathormone** from the parathyroid glands and **calcitonin** from the thyroid gland.

Differences between Decalcified and Dried bones

Decalcified bone	*Dried bone*
1. Inorganic substances are removed with the help of dilute HCl. 2. Living structures are present. 3. Bone marrow cavity is with bone marrow.	1. It is subjected to high temperature. It contains inorganic substances. 2. Living structures are absent. 3. Bone marrow cavity is empty.

Differences between Red bone marrow and Yellow bone marrow

Red bone marrow	*Yellow bone marrow*
1. It is the red-coloured active vascular tissue in the long bones. 2. It has a few fat cells. 3. It produces blood corpuscles. 4. During foetal life and at birth there is red bone marrow throughout the skeleton.	1. It is the yellow-coloured inactive vascular tissue in the long bones. 2. It has more fat cells. 3. It produces blood corpuscles in emergency. 4. After about the fifth year the red bone marrow is gradually replaced in the long bones by yellow bone marrow.

Differences between Lamellae and Lacunae in bones

Lamellae	*Lacunae*
1. They are the plates of matrix in the bone. 2. They are impregnated with calcium salts. 3. Canaliculi run through lamellae. 4. In a mammalian bone, Haversian, circumferential and interstitial lamellae are present.	1. They are spaces around bone cells (osteocytes). 2. They are filled with a fluid secreted by osteocytes. 3. Lacunae lead into canaliculi. 4. They are not of different types.

Differences between Bone and Cartilage

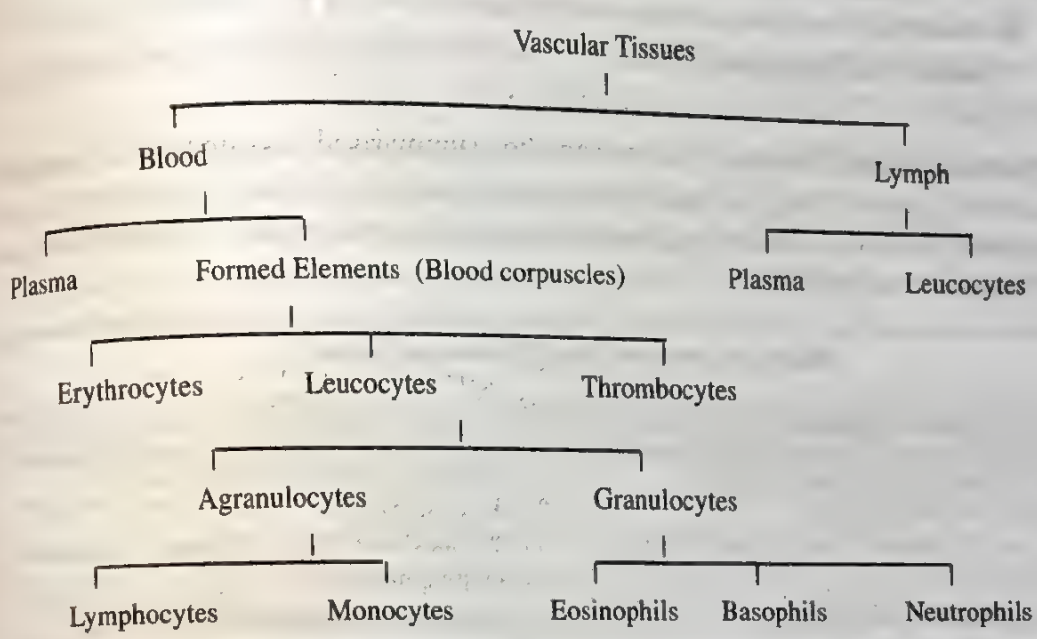
Bone	*Cartilage*
1. It is hard. 2. Matrix has an inflexible material, the **ossein**. 3. Matrix always contains calcium salts. 4. Matrix occurs in lamellae. 5. Osteocytes give off protoplasmic processes. 6. Lacunae give off canaliculi. 7. Outer and inner layers of osteoblasts of a bone produce osteocytes.	1. It is soft. 2. Matrix has a flexible material, the **chondrin**. 3. Calcium salts may or may not be present in the matrix. 4. Matrix occurs in a homogenous mass (*i.e.*, lamellae are absent). 5. Chondroblasts do not have protoplasmic processes. 6. Lacunae do not have canaliculi. 7. Such layers of chondroblasts are not present.

8. Bones have rich blood supply. 9. Bone marrow is present that produces blood corpuscles. 10. Growth in bone is bi-directional.	8. Cartilages do not have rich blood supply. 9. Such structure is absent. 10. Growth is cartilage is unidirectional.

(B) Vascular Tissues (= Fluid Tissues). Special Features. Vascular tissues are motile connective tissues consisting of fluid matrix and free cells. The matrix is without fibres. The matrix is not secreted by the cells present in it. Vascular tissues transport the materials from one place to the other.

Types. The vascular tissues are of two types : blood and lymph.

Table showing various components of Vascular Tissue



I. Blood

Blood is a mobile connective tissue composed of a fluid, the plasma and the cells, the blood corpuscles. Blood is basis of life. Blood is the softest tissues in the body. Fluids outside the cells are generally called **extracellular fluids** (ECF). Blood forms about 30–35 percent of the ECF. The volume of blood in an adult person of 70 kg weight is about 5.5 litres. It is a slightly alkaline fluid having *pH* 7.4. *p*H of blood in arteries is more than in veins.

Composition. As stated above blood is composed of a watery fluid called **plasma** and floating bodies termed **formed elements** (*e.g.*, blood corpuscles).

(A) Plasma.

It is slightly alkaline non-living intercellular substance which constitutes about 60% part of the blood. It is a pale yellow but transparent and clear fluid.

Composition of Plasma. 1. **Water**. Water alone forms about 90% to 92% of the plasma. Solids form about 8% of the plasma.

2. **Mineral Salts**. These are chlorides, bicarbonates, sulphates and phosphates of sodium, potassium, calcium, iron and magnesium. All salts constitute about 0.9% of plasma. Buffer of the blood is **sodium bicarbonate**.

3. **Nutrients**. These include glucose, fatty acids, phospholipids, cholesterol, fats, aminoacids, nucleosides, etc. Mineral salts have been mentioned above.

4. **Plasma Proteins**. They constitute about 7 to 8% part of plasma. These mainly include albumin, globulin, immunoglobulin, prothrombin and fibrinogen.

5. **Defence Compounds**. **Immunoglobulins** which act as antibodies and some other substances, such as **lysozyme** (a polysaccharide) and **properdin** (a large protein) are always found in the plasma. They destroy bacteria, viruses and toxic substances that may enter into the blood from outside.

6. **Excretory Substances**. These include ammonia, urea, uric acid, creatine, creatinine, etc.

7. **Dissolved Gases**. Water of blood plasma contains oxygen, carbon dioxide and nitrogen in dissolved form.

8. **Anticoagulant**. Blood plasma contains a conjugated polysaccharide, the **heparin** which prevents coagulation of blood inside blood vessels.

9. **Hormones**. These are secreted and released in blood by endocrine glands.

10. **Vitamins and Enzymes**. Different kinds of vitamins and enzymes are present in the blood plasma.

Functions of Blood Plasma. These can be summarised as under (i) transport, (ii) retention of fluid in blood, (iii) maintenance of blood *p*H, (iv) body immunity, (v) prevention of blood loss, (vi) conducting heat to skin for dissipation and (vii) uniform distribution of heat all over the body.

Differences between Blood Plasma and Serum

Blood Plasma	*Blood Serum*
1. It is the fluid minus blood corpuscles. 2. It is faint yellow in colour. 3. It has fibrinogen and other clotting materials. 4. It takes part in blood clotting.	1. It is liquid minus clotting elements. 2. It is pale yellow. 3. It does not have fibrinogen and other clotting materials. 4. It does not take part in blood clotting.

Functions of Plasma Proteins — Refer to Chapter-18 "Body fluids and their circulations".

(B) Formed Elements (Blood Corpuscles).

Formed elements or blood corpuscles are of the following three types : Erythrocytes, Leucocytes and Thrombocytes.

(a) Erythrocytes (Red Blood Corpuscles or RBCs)

They are the most abundant cells in the human body.

Size. Human RBCs are smaller than the white blood corpuscles. They are 7-8 μm in diameter.

Number. The total number of RBCs per microlitre ($1\mu l = 1\ mm^3 = 10^{-6}\ l$) of blood is termed as the **total count of RBCs**. A normal adult man and woman have 5 and 4.5 million RBCs per cubic millimetre of blood respectively. Thus the total count of RBCs is more in man than in a woman. It is due to the fact that women undergo menstruation. Less amount of haemoglobin leads to **anaemia**. Anaemia may be caused by loss of blood (haemorrhage), destruction of RBCs (haemolysis or faulty formation of blood). The increase in number of RBCs may be during muscular exercise to meet the increased demand of oxygen and at high altitudes to cope with the low oxygen content of the air. An abnormal rise in RBC count in

called **polycythemia**. Descrease in the number of RBCs is called **erythrocytopenia** which causes oxygen shortage in the blood and tissues. It is important to note that the oxygen shortage stimulates the kidney cells to secrete a hormone named **erythropoietin**, into the blood. Erythropoietin stimulates the bone marrow to increase the production of RBCs.

Formation. Formation of erythrocytes is called **erythropoiesis.** In the early few weeks of embryonic life, primitive nucleated RBCs are produced in the **yolk sac**. (one of the embryonic membranes). In later embryonic stage, RBCs are mainly produced by the liver and spleen. But from birth onwards, RBCs are produced by bone marrow (throughout life). **Hemocytoblasts** in red bone marrow give rise to mature RBCs. Iron and proteins are necessary raw materials for the synthesis of haemoglobin. However vitamin B_{12} and folic acid stimulate the maturation of RBCs. Thus iron, protein, vitamin B_{12} and folic acid are essential for the formation of haemoglobin and RBCs. Deficiency of any of these nutrients can cause anaemia. Excess RBCs are stored in the spleen.

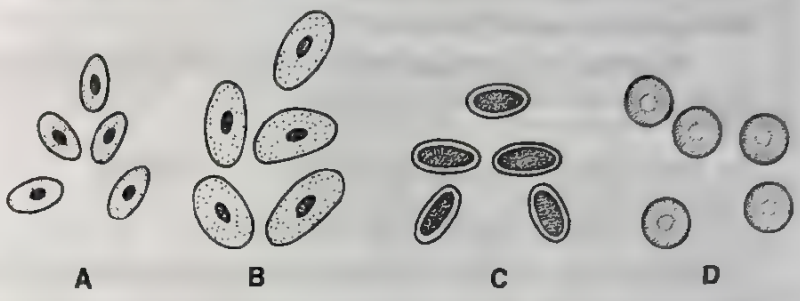


Fig. 7.29. Comparison of erythrocytes of different vertebrates. A, fish; B, Amphibian; C, bird; D, Man.

Life Span. The life of a RBC is about 120 days.

Functions of RBCs. (i) **Transport of O_2.** Haemoglobin of RBCs readily combines with oxygen to form **oxyhaemoglobin**. In the tissues oxyhaemoglobin readily gives up its oxygen. This oxygen is used for oxidation of food. (ii) **Transport of CO_2.** RBCs also participate in transporting carbon dioxide from tissues to lungs. Carbon dioxide combines with potassium carbonate of the red blood corpuscles to form **potassium bicarbonate** in the presence of an enzyme **carbonic anhydrase**. Carbon dioxide also combines with the amino group ($—NH_2$) of the haemoglobin of red blood corpuscles to form **carbamino-haemoglobin**. (iii) **Maintenance of *p*H of blood.** Moreover, the haemoglobin is an excellent acid base buffer which is largely responsible for maintaining the *p*H of blood. Acidity of blood results haemoglobin to carry less oxygen.

- The old worn-out red blood corpuscles are phagocytosed and destroyed by macrophages in the liver. The pigment part (heme) is processed mainly first to bile pigment **biliverdin** (green), then to another bile pigment **bilirubin** (yellow) which is secreted in the bile. The pale yellow colour of the blood plasma is largely due to bilirubin.
- **Jaundice.** When all the bilirubin is not excreted from the body, the skin and mucous membranes assume a yellowish colour. This condition is called **jaundice.**
- Amphibian RBCs are the largest among vertebrates.
- Salamander *Amphiuma means* has largest RBCs about 80 μm in diameter.
- **Musk deer** (*Tragulus Javanicus*) has the smallest RBCs (1.5 μm)
- The absence of nucleus in mammalian RBCs helps to accommodate maximum amount of haemoglobin.
- Concave surface of mammalian RBCs helps in increasing the surface area.
- Life span of frog's RBCs is about 100 days.
- In frog main sites of haemopoiesis are liver and spleen but in tadpoles, kidneys are also haemopoietic.
- RBCs of mammal lose nucleus during **reticulocyte Stage**.

• The adult haemoglobin molecule is made of 2 **alpha chains** with 141 amino acids each and 2 **beta chains** with 146 amino acids each.

• People living in hills have more RBCs.

Some Other Respiratory Pigments. In most invertebrates, respiratory pigments other than haemoglobin are present for the transport of oxygen. For example, prawns, crabs and *Pila* contain a blue copper protein complex pigment called **haemocyanin**. Some annelids (*e.g., Sabella*) contain green iron protein pigment called **chlorocruorin**.

Rouleaux. In resting and slow flowing blood, the RBCs aggregate to form **rouleaux** (Singular-roulear) (the RBCs are piled on top of each other). Fibrinogen favours rouleaux formation.

(b) Leucocytes (White Blood Corpuscles or WBCs).

Leucocytes do not have haemoglobin.

Number. The number of leucocytes per microlitre of blood is called the **total leucocyte count** (TLC). This varies from 4–11 × 10^3/cu mm of blood in humans. Thus, they are less in number than the RBCs. Rise in WBC count is termed **leucocytosis**. Increased TLC shows that there is acute bacterial infection. Abnormal increase of WBCs is in malignancies like **leukemia** (blood cancer). Fall in WBC count is called **leukopenia**. In some conditions, such as folic acid deficiency, the total count of WBC decreases. The total count of WBC is useful in diagnosing various diseases. Normal or low TLC is in viral infection, malaria, typhoid or tuberculosis.

Differential Leucocyte Count (DLC) means detecting the number of different kinds of leucocytes.

Normal DLC (Adults)

Neutrophils	40 — 70%
Lymphocytes	20 — 40%
Monocytes	2 — 10%
Eosinophils	1 — 6%
Basophils	0 — 1%

Shape. The leucocytes are rounded or irregular in shape. They can change their shape like *Amoeba* and are thus, capable of amoeboid movement. This enables them to squeeze out of blood capillaries into the tissues (extra vascular regions). This process is called **diapedesis**.

Size. The WBCs are larger than the RBCs. Their size is from 12 to 20 μm.

Colour. The WBCs are colourless.

Structure. A leucocyte consists of cell membrane, nucleus and cytoplasm. The cytoplasm contains mitochondria, Golgi apparatus, centrioles besides other cell organelles.

Types. The leucocytes are of two main types : Agranulocytes and granulocytes.

Agranulocytes. The granules are not found in the cytoplasm of these cells. The agranulocytes are of two types.

(i) **Lymphocytes.** They are smaller in size containing scant cytoplasm with large rounded nucleus. They are nonmotile and nonphagocytic. They produce antibodies to destroy microbes and their toxins reject grafts and kill tumour cells. They also help in healing of injuries. Lymphocytes exist in two major groups in circulation. These are **B-** and **T-lymphocytes**

Differences between B-Lymphocytes (B-cells) and T-Lymphocytes (T-cells)

B-Cells	*T-Cells*
1. They form a part of the humoral immune system.	1. They form a part of the cell-mediated immune system.
2. They are processed in the liver or bone marrow.	2. They are processed in the thymus gland.
3. They release the antibodies which finally enter the blood.	3. They do not release the antibodies.
4. They produce antibodies to kill the antigens.	4. The whole cell directly attacks the antigens.
5. They defend the body against invading bacteria/virus. They do not reach against transplants and cancerous tissues.	5. They defend the body against pathogens but also attack the transplants and the cancerous cells.

(ii) **Monocytes**. They are the **largest** of all types of leucocytes and somewhat amoeboid in shape. They have much cytoplasm. The nucleus is bean-shaped. They are motile and *phagocytic* in nature and engulf bacteria and cellular debris. Generally they change into macrophages after entering tissue spaces.

Granulocytes. They contain granules in their cytoplasm. Their nucleus is irregular or lobed or subdivided. According to their staining property, the granulocytes are divided into three types.

(i) **Eosinophils**. The nucleus is two lobed. They have coarse granules. Their granules take acidic stains (*e.g.*, eosin). Their number increases in people with allergic conditions such as asthma or hay fever. They also help in dissolving blood clot. They are *nonphagocytic*. They seem to play a part in the immune system. They have some similarity to lysosomes. Eosinophils can attach themselves to parasitic forms and cause their destruction by liberating lysosomal enzymes on their surface. Cytoplasm contains abundant coarse granules which pick acidic stain like eosine. They are, therefore, also called **acidophils**. The increase in number of acidophils during allergy is called **Eosinophilia**.

(ii) **Basophils**. The nucleus is usually three lobed. They have less number of coarse granules. Their granules take basic stain (*e.g.*, methylene blue) strongly. Both mast cells and basophils liberate *histamine*, *heparin* as well as smaller quantities of *bradykinin* and *serotonin*. They are probably like mast cells of connective tissue.

(iii) **Neutrophils**. The nucleus is many lobed. They have fine granules. They stain weakly with both acid and basic stains. Neutrophils are the most numerous of all leucocytes. Certain neutrophils in female mammals possess a small spherical lobe attached to their nucleus by a stalk. This lobe is called **drum stick** (= **sex chromatin**) or **Barr body**. Barr is the name of the scientist. Drumstick is formed by transformation of an X-chromosome. They eat harmful germs and are, therefore, *phagocytic* in nature.

Formation. Formation of leucocytes is called **leucocytosis** or **leucopoeisis**. The granulocytes and monocytes are formed only in bone marrow. Lymphocytes are produced mainly in lymph nodes; spleen, thymus, tonsils, bone marrow and Peyer's patches of small intestine.

Life Span. The life of the granulocytes once released from the bone marrow is normally 4 to 8 hours circulating in the blood and another 4 to 5 days in the tissues. The monocytes also have a short life span of 10 to 20 hours. The lymphocytes have life spans of few days or months or even years, but this depends on the body's need for these cells.

Differences between Red and White Blood Corpuscles of Man

Red Blood Corpuscles-- RBCs (Erthrocytes)	*White Blood Corpuscles-- WBCs (Leucocytes)*
1. They are smaller, more numerous and longer lived cells than the WBCs.	1. They are larger, fewer, shorter-lived cells than erythrocytes.
2. RBCs have a fixed form. RBCs of man are circular, biconcave and enucleated.	2. WBCs are rounded but can change their shape.
3. They occur only in blood vessels.	3. They can escape from capillaries into the tissues (diapedesis).
4. RBCs lose cell organelles (ER, mitochondria, ribosomes, centrioles) during development.	4. WBCs retain cell organelles (E.R., mitochondria ribosomes, centrioles).
5. They have haemoglobin.	5. They lack haemoglobin.
6. RBCs are yellowish when seen singly and red when viewed in bulk.	6. WBCs are colourless.
7. They form rouleaux.	7. They do not form rouleaux.
8. RBCs are alike having no subtypes.	8. WBCs are of 5 types : lymphocytes, monocytes, eosinophils, basophils and neutrophils.
9. They carry O_2 and CO_2.	9. They act as soldiers and scavengers.
10. RBCs are produced by yolk sac, liver, spleen and bone marrow.	10. WBCs are produced by bone marrow, lymph nodes, spleen, tonsils and Peyer's patches.

(C) Thrombocytes (= Blood platelets).

In mammals thrombocytes are called blood platelets.

Number. They are fewer than the RBCs and more than the WBCs in number. There are about 250,000 platelets in a cubic millimetre of blood. Increase and decrease in the number of platelets is known as **thrombocytosis** and **thrombocytopenia** respectively.

Shape. Blood platelets are really cell fragments rather than true cells. They are rounded or oval disc like bodies.

Size. Platelets are 2–3 micrometres in diameter. Thus they are much smaller than both the red and white blood corpuscles.

Colour. Platelets are colourless.

Structure. They are flat and non-nucleated fragments of the cells. They are simply bits of protoplasm, bounded by a membrane and contain a few cell organelles and secretory granules in the cytoplasm. They have a group of basophilic granules in the centre which give the appearance of a nucleus.

Formation. Platelets are formed from the **megakaryocytes** (very large cells of the bone marrow). Formation of thrombocytes is called **thrombopoiesis.**

Life span. Normal life span of blood platelets is about a week.

Function. When an injury is caused, the blood platelets release certain chemicals which are called the **platelet factors** (*e.g.*, **thromboplastin**). The platelet factors help in the clotting of blood.

Spindle Cells or **Thrombocytes.** These are found in vertebrates other than mammals. They are biconvex, nucleated cells with granular cytoplasm. Like platelets, spinde cells take part in blood clotting.

Haemopoiesis. The process of formation of blood is called **haemopoiesis** and the

tissues which form blood corpuscles are termed the **haemopoietic tissues**. In frog, spleen, liver and lymph nodes are main sites of haemopoiesis. During rains haemopoiesis also occurs in bone marrow due to an active life of frog. In tadpoles kidneys are also haemopoietic.

In mammals, yolk sac (an embryonic membrane), liver, bone marrow, lymph nodes, spleen and thymus are the heomopoietic organs in the embryo. In adults most of the blood corpuscles are formed in the red bone marrow of long bones. Lymphocytes are, however, formed in thymus, some in spleen, lymph nodes, tonsils and Peyer's patches.

Table : Summary of Human Blood Corpuscles

Name and Number/ Percentage	*Colour and Structure*	*Formation and Life Span*	*Function*
1. **Erythrocytes** (RBCs) In man and woman 5 and 4.5 million per cubic millimetre of blood. Number increases during exercise and at high altitudes.	Look yellow when seen singly and red when viewed in bulk, circular, biconcave, denucleated, elastic, plasma membrane, homogenous cytoplasm with haemoglobin ; cell organelles such as ER, mitochondria, ribosomes, centrioles absent; 7–8 μm wide, 1–2 μm thick.	By yolk sac in the early few weeks of embryonic life, in later embryonic stage by the liver and spleen, from birth onwards by bone marrow. Life 120 days.	Transport of oxygen and some amount of carbon dioxide.
2. **Leucocytes (WBCs)** 5,000 to 10,000 per cubic millimetre of blood. Number increases during infection.	Colourless, rounded or irregular, nucleated, 12 to 20 μm wide.	Bone marrow, lymph nodes, spleen, thymus, tonsils and Peyer's patches.	Act as soldiers, scavangers, some help in healing.
(i) **Agranulocytes**	Cytoplasm lacks granules, nucleus not lobed.		
(a) *Lymphocytes* 20–45%	Large rounded nucleus, scant cytoplasm.	Lymph nodes, spleen, thymus, tonsils, bone marrow, Peyer's patches. Life few days or months or even years.	Motile non-phagocytic, secrete antibodies, help in healing.
(b) *Monocytes* 2–10%	Largest of all types of leucocytes. Nucleus bean-shaped, enough cytoplasm.	Bone marrow, Life 10 to 20 hours.	Motile, phagocytic, engulf germs and cell debris, often change into macrophages.
(ii) **Granulocytes**	Cytoplasm has granules, nucleus lobed.		
(a) *Eosinophils* 1–6%	Bilobed nucleus, coarse granules in cytoplasm, take acidic stain.	Bone marrow, life 4 to 8 hours in the blood 4 to 5 days in the tissue.	Non-phagocytic, have antihistamine properties (= antiallergic properties), play role in immunity.
(b) *Basophils*	Usually three lobed	Bone marrow, life 4 to	Release heparin and histamine.

0–1%	nucleus, less number basic stain.	8 hours in the blood,	Thus they act like mast cells of con nective tissue.
(c) *Neutrophils* 40–75%	Many lobed nucleus, fine granules; take acidic as well as basic stains.	Bone marrow, life 4 to 8 hours in the blood, 4 to 5 days in the tissue.	Phagocytic ; engulf germs and dead cells.
3. **Platelets** 250,000 platelets per cubic millimetre of blood.	Colourless, rounded or oval, non-nucleated frag-ments of the cells.	Bone marrow, about a week.	Help in blood clotting.

Functions of Blood

On the basis of the above description, the general functions of blood can briefly be summarised as below.

1. **Transport of Food Materials**. Blood transports the digested food from the alimentary canal to the different body cells.

2. **Transport of Respiratory Gases**. Oxygen is carried from the respiratory organs to the tissues and carbon dioxide from the tissue to the respiratory organs by blood.

3. **Transport of Hormones**. Hormones are carried by blood from the endocrine glands to the places of use.

4. **Transport of Excretory Matter**. Blood transports the excretory matter to the kidneys or other excretory organs.

5. **Transport of Heat**. Blood allows the transfer of heat from the deeper tissue to surface of the body where it can be lost.

6. **Defence against Infection**. Some white blood corpuscles are phagocytic in action, however, certain white blood corpuscles produce antitoxins to neutralize the toxins released by the foreign germs.

7. **Temperature Regulation**. Blood maintains the body temperature to a constant level after distributing heat within the body.

8. **Water Balance**. Blood maintains water balance to a constant level by bringing about constant exchange of water between circulating blood and tissue fluid.

9. **Maintenance of *p*H.** Blood helps to regulate the *p*H of the body.

10. **Prevention of Excessive Loss of Blood**. When any part of the body is injured, loss of blood is prevented by the formation of a clot.

11. **Helps in Healing**. Blood maintains necessary supplies for the repair of damaged tissue. Eosinophils and basophils help in the healing of wounds.

12. **Maintenance of Physiological Co-operation**. Blood maintains a physiological co-operation between parts of the body by circulating from one to other parts.

Differences Between Adipose Tissue and Blood Tissue

Adipose Tissue	*Blood Tissue*
1. It is soft gel-like connective tissue.	1. It is a fluid connective tissue.
2. Adipose cells contain fat droplets.	2. Adipose cells are not present.
3. Matrix is secreted by the cells.	3. Matrix is not secreted by the cell.
4. The adipose tissue contains fibres.	4. Fibres are not conspicuous.
5. It is a storage tissue because it stores fat.	5. It is a transport tissue because it transports various materials.

II. Lymph

Definition. Lymph is a mobile connective tissue comprising lymph plasma (fluid) and lymph corpuscles (cells).

Composition. (A) Lymph Plasma. It is similar to that of blood but has fewer blood proteins, less calcium and phosphorus and high glucose concentration. Mainly globulin proteins are present which are actually antibodies. Other components of the lymph plasma are very much like that of blood plasma, *i.e.,* organic, inorganic substances, water, etc.

(B) Lymph Corpuscles. These are floating amoeboid cells, the leucocytes (white blood corpuscles), which are mostly lymphocytes. Erythrocytes (red blood corpuscles) and platelets are absent in lymph.

Lymphoid Organs. The organs which secrete lymph are called lymphoid organs. Besides the lymph nodes, tonsils, thymus gland, spleen and Peyer's patches are the other lymphoidal organs. Liver also produces lymph. The spleen is a large lymphatic organ in the body.

Functions of Lymph

1. Lymph acts as a "middle man" which transports oxygen, food materials, hormones, etc., to the body cells and brings carbon dioxide and other metabolic wastes, from the body cells to blood and then finally pours the same into the venous system.
2. Body cells are kept moist by the lymph.
3. Lymph nodes produce lymphocytes. Lymph takes lymphocytes and antibodies from the lymph nodes to the blood.
4. It destroys the invading microorganisms and foreign particles in the lymph nodes.
5. It absorbs and transports fat and fat soluble vitamins from the intestine. Lymphatic capillaries present in the intestinal villi are called **lacteals** which are associated with absorption and transportation of fat and fat soluble vitamins.
6. It brings plasma protein macromolecules synthesized in the liver cells and hormones produced in the endocrine glands to the blood. These molecules can not pass into the narrow blood capillaries but can diffuse into the lymphatic capillaries.
7. Lymph maintains the volume of the blood. As soon as the volume of the blood reduces in the blood vascular system, the lymph rushes from the lymphatic system to the blood vascular system.

Differences between Blood and Lymph

Blood	*Lymph*
1. It consists of plasma, erythrocytes, leucocytes and platelets.	1. It consists of plasma and leucocytes (lymphocytes most abundant).
2. It is red in colour due to the presence of haemoglobin in erythrocytes.	2. It is colourless as haemoglobin is absent.
3. Its plasma has more proteins, calcium and phosphorus.	3. Its plasma has fewer proteins and less calcium and phosphorus.
4. Glucose concentration is less in blood.	4. Glucose concentration is higher in lymph.
5. Amount of CO_2 and other metabolic wastes is normal.	5. Amount of CO_2 and other metabolic wastes is much more.
6. It carries materials towards and away from the tissue, therefore, it acts as a "vehicle".	6. It transfers materials from the blood to the body cells and vice-versa, therefore, it acts as "middle man".

(C) Reticular Connective Tissue :

Structure. This tissue consists of star-shaped **reticular cells** whose **protoplasmic**

processes join to form a cellular network. The **reticular fibres** are present on the reticular cells. They are composed of a protein called **reticulin.** Matrix and some other cells such as macrophages, lymphocytes and adipose cells are also present (Fig. 7.30)

Location. Reticular connective tissue is present in the liver, spleen, lymph nodes, thymus, tonsils, bone marrow and lamina propria of the gut wall.

Functions. The reticular connective tissue is especially adapted to provide strength and support as it forms the supporting framework (stroma) of many organs. It also helps to bind together the cells of smooth muscles. The reticular cells are phagocytic and form defence mechanism of the body.

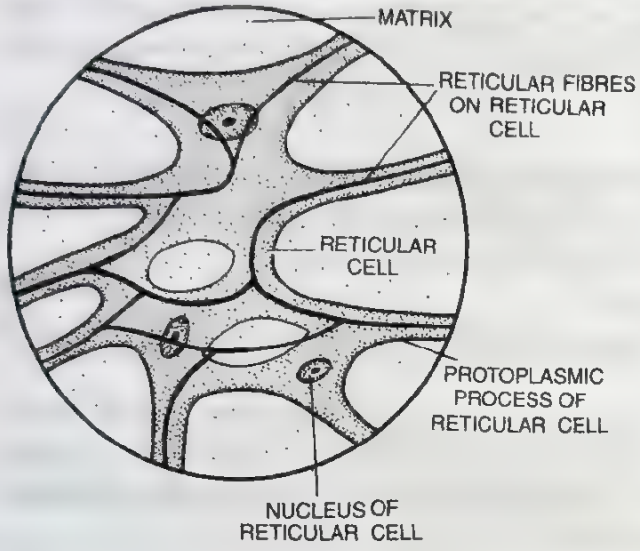


Fig. 7.30. Recticular connective tissue

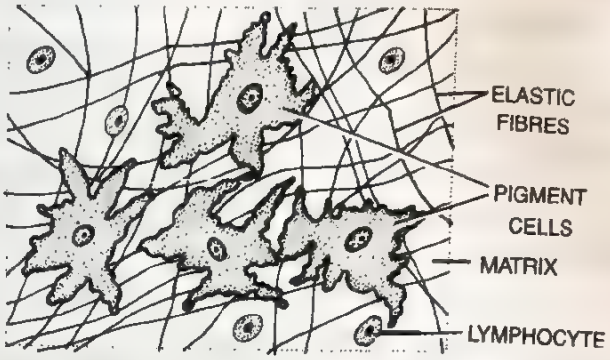


Fig. 7.31. Pigmented connective tissue.

(D) Pigmented Connective Tissue :

Structure. The cells are irregular in shape and are called **pigment cells** (= chromatophores or melanophores; Fig. 7.31) which contain yellowish brown, black or blue **melanin** pigment granules. Melanin is in fact, produced by other cells called **melanocytes.** Chromatophores simply phagocytise the melanin from melanocytes like macrophages.

Location. Pigmented connective tissue is present in the choroid, ciliary body and iris of the eye and dermis of the human skin.

Functions. The pigmented connective tissue gives colour to the structures.

(E) Mucoid Connective Tissue. In addition to above mentioned connective tissues, mucoid tissue occurs as a foetal or embryonic connective tissue. It is present in the umbilical cord. The most conspicuous component of the mucoid tissue is a jelly like substance, called **Whartson's Jelly.** Some delicate collagen fibres and primitive type of fibroblasts are also present. Mucoid tissue (mucous connective tissue) also occurs in vitreous humour of the eye and in comb of cock.

Functions of Connective Tissues

1. **Attachment.** Their chief function is to bind other tissues together in the organs.
2. **Storage.** Certain connective tissues such as **adipose tissues** store fat.
3. **Support.** Skeletal connective tissues like **bones** and **cartilages** provide the body with a supporting skeletal frame work.

4. **Transport**. Fluid connective tissues such as blood and lymph transport various materials in the body.

5. **Defence and Scavenging**. Plasma cells synthesize antibodies, *viz.*, macrophages. Lymphocytes ingest cell debris, harmful bacteria and foreign matter. Thus these cells of connective tissues are protective in function.

6. **Shock-proof Cushions**. The jelly-like gound substance of connective tissues acts as shock absorber around some organs such as eye balls and kidneys.

7. **Formation of Blood Corpuscles**. The bone marrow produces blood cells.

8. **Packing Material**. Areolar tissue acts as packing material in various organs.

9. **Repair**. Collagen fibres of connective tissue help in repair of injured tissues.

Differences Between Connective and Epithelial Tissues

Connective Tissue	*Epithelial Tissue*
1. It binds different tissues or organs and provides support.	1. It covers the external or internal surfaces of body parts.
2. The cells are widely separated and do not form glands.	2. The cells are closely set and form glands.
3. Extracellular material is large in quantity.	3. Extracellular material is small in quantity.
4. It has blood vessels.	4. It usually does not have blood vessels.

III. MUSCLE TISSUE (MUSCULAR TISSUE)

Origin. Muscular tissue in general develops from the **mesoderm** of the embryo but the muscles of the iris of the eye and myoepithelial cells of the salivary, mammary and sweat glands arise from the ectoderm of the embryo.

General Structure. Myo, sarco and **motor** are concerned with muscles. This tissue constitutes the muscles, made up of cells, which are in the form of contractile fibres varying in lengths. The fibres are bound together by connective tissues but they have no intercellular substance. **Myoblasts** give rise to muscle fibres. **Myocytes** (= sarcocytes) are muscle cells. Each fibre consists of fine fibrils called **myofibrils**, present in the cytoplasm known as **sarcoplasm**. Sometimes the muscle fibre is externally covered by a membrane, termed as **sarcolemma**.

Special Properties. The special property of muscular tissue is **contractility** *i.e.*, the cells of muscular tissue can shorten considerably and return to the original relaxed state. The muscle cells contract in a definite direction. Another property of muscle is the **electrical excitability.** It is due to the energy stored in the electrical potential difference across the plasma membrane.

Functions of Muscular Tissue. 1. It brings about movements of the body parts and locomotion of the individual.

2. Muscles are responsible for peristalsis in tubular viscera, heart beat, production of sound, etc.

3. Facial expression also depends on muscles.

4. It supports the bones and other structures.

5. Muscles are required for delivering a baby.

A **whole muscle** (Fig. 7.32) is covered by a connective tissue sheath, the **epimysium**. Beneath the epimysium each skeletal muscle consists of many muscle fibres arranged in

cardiac muscle fibres. They have very rich blood supply. They have the property of contraction, even when they are isolated from the body temporarily.

Similarities between Cardiac and Skeletal Muscles. Both cardiac and skeletal muscles are made up of elongated fibres which have numerous myofibrils. The myofibrils of cardiac muscle have the same structure as those skeletal muscle and are made up of actin and myosin filaments. The cardiac and skeletal muscle fibres have dark and light bands. The connective tissue framework and the capillary network around cardiac muscle fibres are similar to those in skeletal muscle.

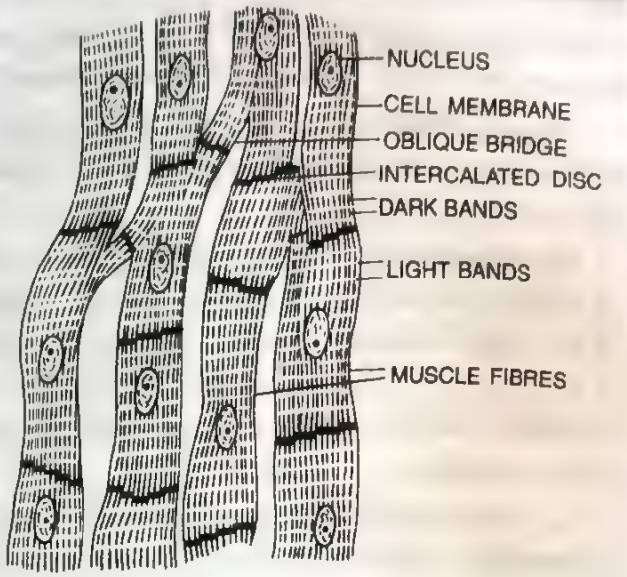


Fig. 7.35. Cardiac Muscle Tissue.

Similarities between Cardiac and Smooth Muscles. Both cardiac and smooth muscles are uninucleate containing nucleus at the centre and are involuntary in function.

Differences Between Striated, Non-striated and Cardiac Muscle Fibres

Striated	*Non-striated*	*Cardiac*
1. They are present in the limbs, body walls, tongue, pharynx and beginning of oesophagus.	1. They are present in the oesophagus (posterior part only), urino-gential tract, urinary bladder, vessels, iris of eye, dermis of skin, and arrector pili muscles of hair.	1. They are present in the wall of the heart, pulmonary veins and superior vena cava.
2. Cylindrical.	2. Spindle shaped.	2. Cylindrical.
3. Fibres unbranched.	3. Fibres unbranched.	3. Fibres branched.
4. Multinucleate.	4. Uninucleate.	4. Uninucleate.
5. Bounded by sarcolemma.	5. Bounded by plasmalemma.	5. Bounded by sarcolemma.
6. Light and dark bands present.	6. Light and dark bands absent.	6. Faint light and dark bands present.
7. No oblique bridges and intercalated discs.	7. No oblique bridges and intercalated discs.	7. Oblique bridges and intercalated discs present.
8. Nerve supply from central nervous system.	8. Nerve supply from autonomic nervous system.	8. Nerve supply from the brain and autonomic nervous system.
9. Blood supply is abundant.	9. Blood supply is scanty.	9. Blood supply is abundant.
10. Very rapid contraction.	10. Slow contraction.	10. Rapid contraction.
11. They soon get fatigued.	11. They donot get fatigued.	11. They never get fatigued.
12. Voluntary	12. Involuntary	12. Involuntary

Other Contractile Cells

In addition to three types of muscular tissue, there are contractile cells, which are as follows.

1. **Myoepithelial Cells** (= Myoepitheliocytes). These cells are present in salivary glands, mammary glands and sweat glands. They form a sort of epithelium called **myoepithelium**. Myoepithelial cells contract to expel saliva, milk and sweat from the respective glands. Myopithelial cells are innervated by autonomic nerves. They resemble smooth muscle cells and are involuntary. These cells arise from the ectoderm instead of mesoderm.

2. **Myofibroblasts.** These cells resemble fibroblasts but contain actin and myosin arranged as in smooth muscle and are contractile. In fact myofibroblasts are specialised contractile fibroblasts. The contraction of wounds is caused by the shortening of myofibroblasts.

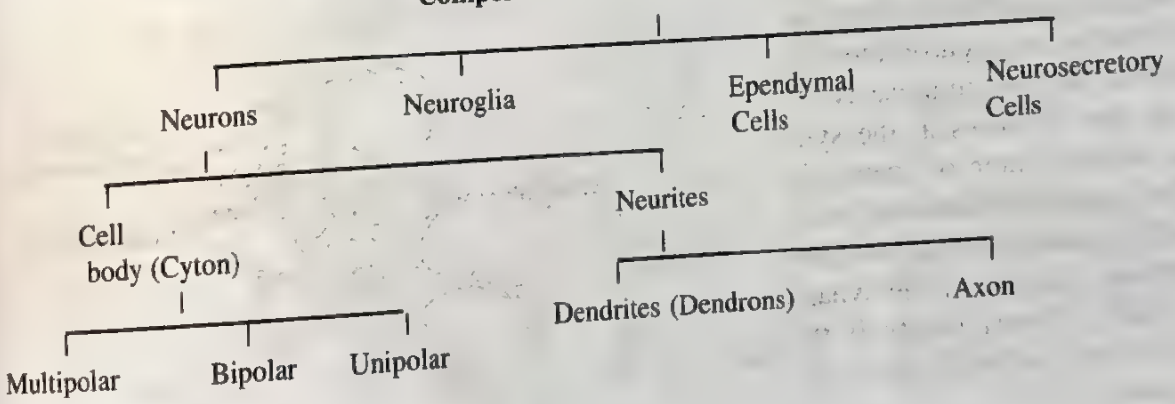
3. **Pericytes.** These cells are found around capillaries and venules. They contain actin and myosin. Pericytes can give rise to myofibroblasts and to mesenchymal tissue which can differentiate into fibroblasts and can form new blood vessels.

IV. NEURAL TISSUE (NERVOUS TISSUE)

Origin. The neural tissue in general develops from the **ectoderm** of the embryo, but the microgliocytes (to be described ahead) arise from the mesoderm of the embryo.

Special Properties. The special properties of the cells of the nervous tissue are, **excitability** and **conductivity**. Excitability is the ability to initiate nerve impulse in response to stimuli (changes outside and inside the body). Conductivity means the ability to transmit a nerve impulse (potential change in membrane of a nerve cell). The reaction is called **response**. The response may be sensation, such as pain or some activity such as muscle contraction or glandular secretion.

Components of Neural Tissue



1. **Neurons.**

Neurons are structural and functional units of neural system. Each neuron consists of the cell body called **cyton** or **perikaryon** or **soma** and nerve fibre (**axon**).

(i) **Cyton (Cell Body).** The cyton contains cytoplasm (**neuroplasm**), prominent spherical nucleus, mitochondria, Golgi bodies, endoplasmic reticulum, ribosomes, lysosomes, fat globules, **Nissl's granules** and **neurofibrils**. Nissl's granules are comparatively large and irregular masses of ribosomes and rough endoplasmic reticulum. They probably synthesize proteins in the cell.

(ii) **Processes of Neuron.** The processes of neurons are called **neurites**. The latter are of two types— **dendrites (dendrons)** and an **axon** or **axis cylinder (neuraxon)**. Dendrites may be one to several but axon is always one. The dendrites are usually shorter and tapering processes. Axon is usually long process of uniform thickness. The part of cyton from where the axon arises is called **axon hillock**. Most sensitive part of neuron is axon hillock. The axon ends in a group of branches, the **terminal arborizations (axon endings**

or **presynaptic knob**). The latter end on other neuron, muscle fibres or gland cells. Certain axons also give rise to side branches, called **collateral fibres**. The neuroplasm of axon contains abundant neurofibrils and mitochondria but Nissl's granules, Golgi bodies, ribosomes and fat globules are absent. The plasma membrane and neuroplasm of axon are respectively called **axolemma** and **axoplasm**.

For details see Chapter 21 – Neural Control and Coordination.

Synapse. A synapse is a site of junction between terminal arborizations of axon of one neuron and the dendrites of another neuron. The fibres, however, do not meet, their cell membranes remain separated by a microscopic gap of about 200 Å. Each neuron receives an impulse through its dendrites and passes it on to the next neuron through synapse. A fresh impulse is set up in the dendrites at the synapse with the help of chemicals called **neurotransmitters**, such as **acetylcholine** produced by the secretory vesicles of the synaptic knobs. *Acetylcholine is the first neurotransmitter to be discovered.*

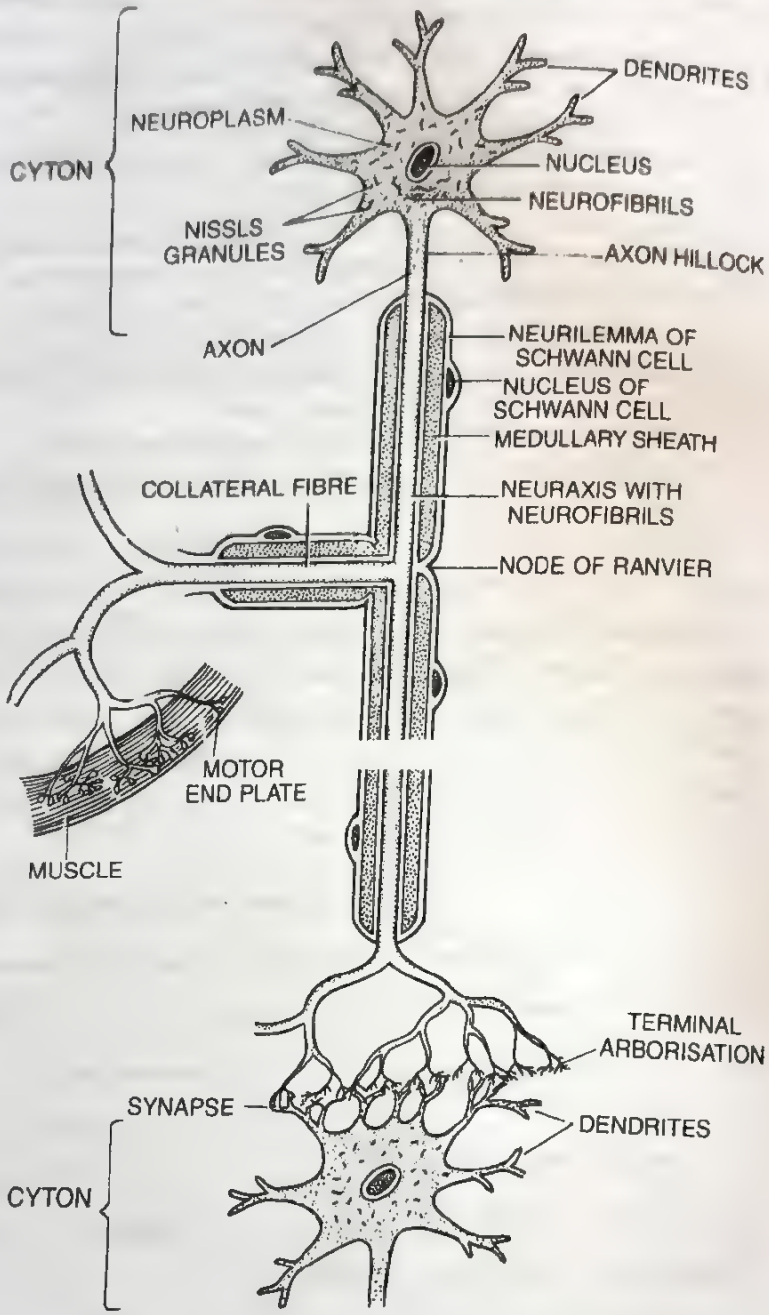


Fig. 7.36. Neurons and medulated nerve fibres showing collateral fibre and synapse.

Synapse between an axon and a dendrite is called **axodendritic synapse** and when it is between an axon and a cell body it is known as **axosomatic synapse**. Mostly there are present axodendrite synapses.

Differences between Axon and Dendrite (Dendron)

Axon	*Dendrite*
1. It is single per neuron.	1. It may be one or many per neuron.
2. It has neurofibrils but no Nissl's granules.	2. It has both neurofibrils and Nissl's granules.
3. It is long and of uniform diameter.	3. It is short and tapering.
4. Branched at the distal end only.	4. Much branched, practically all along.
5. Conducts impulse away from the cyton.	5. Conducts impulse toward the cyton.

Types of Neurons

The neurons are classified on the basis of their structure and function.

(A) On the basis of the structure, the neurons are of five types (Fig. 7.37) :

(i) **Nonpolar** or **Unpolarized Neurons**. Each neuron bears several branched processes. There is no functional difference between dendrites and axon. Each process can bring an impulse to the cyton, or can take it away from the cyton. These neurons are rare in vertebrates but occur in **cnidarians** (= coelenterates) such as *Hydra*.

(ii) **Unipolar Neurons**. Such neuron has a single process (projection), which arises from cyton. True unipolar neurons with an axon and no dendrite are found in early embryos of invertebrates and vertebrates.

(iii) **Pseudounipolar Neurons**. A single process arises from the cyton and then divides into an axon and a dendrite. Such neurons are termed **pseudounipolar neurons**. In adult vertebrates, the dorsal root ganglia of spinal nerves possess pseudounipolar neurons.

(iv) **Bipolar Neurons**. These neurons have only two processes, an axon at one end and a dendrite at another end. Bipolar neurons are found in the retina of eyes, olfactory epithelium and cochlear and vestibular ganglia (cochlea and vestibule are the parts of membranous labyrinth of internal ear).

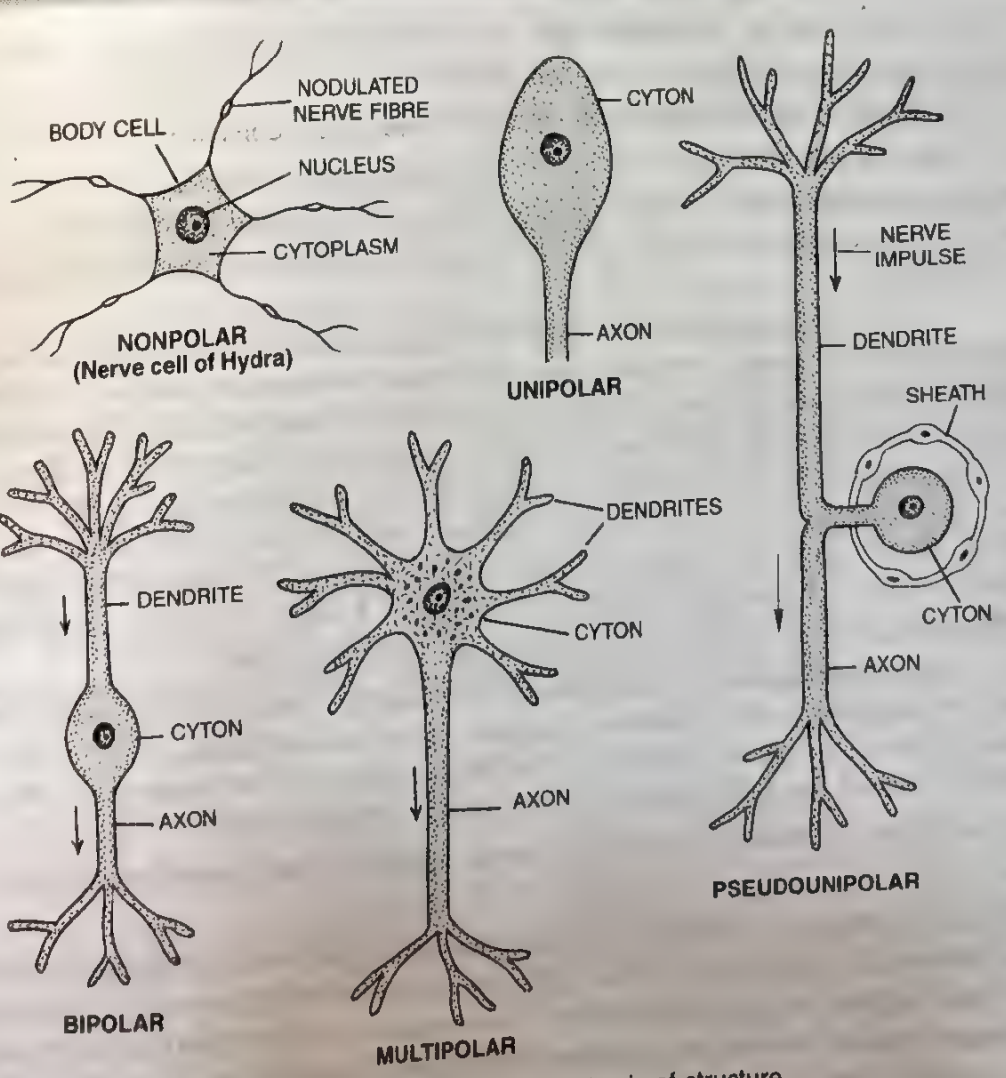


Fig. 7.37. Types of neurons on the basis of structure.

(v) **Multipolar Neurons**. These neurons have several dendrites and an axon. Motor neurons and interneurons are multipolar. They are the most common type of neurons. Multipolar neurons occur in the grey matter of the brain and spinal cord.

(B) On the basis of function, neurons are of three types :

(i) **Sensory** (= **Receptor** or **Afferent**) **Neurons**. They connect sense organs with the central nervous system (brain and spinal cord). They bring sensory impulse from sense organs to the central nervous system.

(ii) **Motor** (= **Effector** or **Efferent**) **Neurons.** They connect the central nervous system to the effectors (muscles and glands). They carry motor impulses from the central nervous system to the effectors.

(iii) **Interneurons** (= **Connector, Relaying** or **Adjustor Neurons**). They are present in the central nervous system and occur between the sensory and motor neurons for distant transmission of impulses. They are neither sensory nor motor, but are meant for integrating and analysing the input of information and distributing it to other parts of nervous system.

Nerve Fibres

Axon or dendrite of a nerve cell covered with one, two or three sheaths is called **nerve fibre**. Dendrites are surrounded only by one sheath. An axon may be surrounded by two or three sheaths.

(A) **On the basis of structure**, the nerve fibres are of two types : medullated or myelinated and non medullated or non-myelinated.

(i) **Medullated** (= **Myelinated**) **Nerve fibres**. They consist of the following parts.

(a) **Axis Cylinder**. It is simply the axon or dendrite of a nerve cell. Its neuroplasm (= **axoplasm**) contains longitudinal neurofibrils and mitochondria. The plasma membrane surrounding the axis cylinder is called **axolemma**. Axolemma conducts the nerve impulses.

(b) **Medullary Sheath** (= **Myelin Sheath**). The medullary sheath is composed of substance called **myelin**. Myelin contains lipids, proteins and water. Thus myelin resembles the plasma membranes of a cell. The medullary sheath serves as an insulating layer, preventing loss of energy of the nerve impulse during its passage along the fibre. It works much in the manner of the coating of an electric wire. The medullary sheath is continuous around the nerve fibres in the central nervous system but in the nerve fibres of the peripheral nerve fibres it is absent at certain points called the **nodes of Ranvier**. The part of a nerve fibre between two successive nodes of Ranvier is called **inter node**. Each segment of the myelin sheath is formed by one **Schwann Cell**.

(c) **Neurilemma** (= **Schwann Cell Sheath**). Outside the myelin sheath there is a layer of Schwann cell cytoplasm which is called **neurilemma**. A single large and flat nucleus is present in the cytoplasm. The neurilemma is continuous over the nodes of Ranvier. As stated above Schwann's cells produce myelin sheath.

A thin layer of connective (areolar) tissue, called the **endoneurium**, covers the neurilemma.

The medullated nerve fibres of the brain and spinal cord lack neurilemma. Due to lack of neurilemma the nerve fibres of the brain and spinal cord do not regenerate after injury. These fibres have an incomplete covering of neuroglia cells which produce the myelin sheath. Neurilemma present round the peripheral nerve fibres (nerve fibres of the cranial and spinal nerves) enables them to regenerate after injury.

Certain axons give out lateral branches, called **collateral fibres**. The latter arise from nodes of Ranvier at right angles.

The medullated nerve fibres are found in the **white matter** of the brain and spinal cord and in the cranial and spinal nerves.

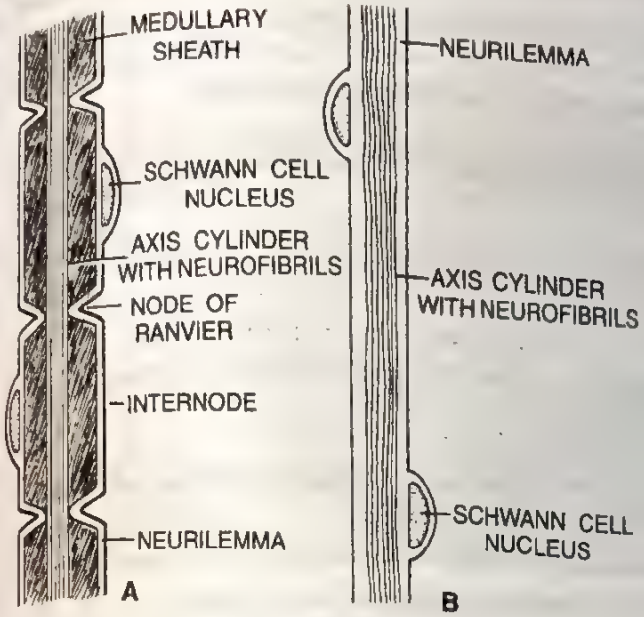


Fig. 7.38. A, medullated nerve fibre. B, Non-medullated nerve fibre.

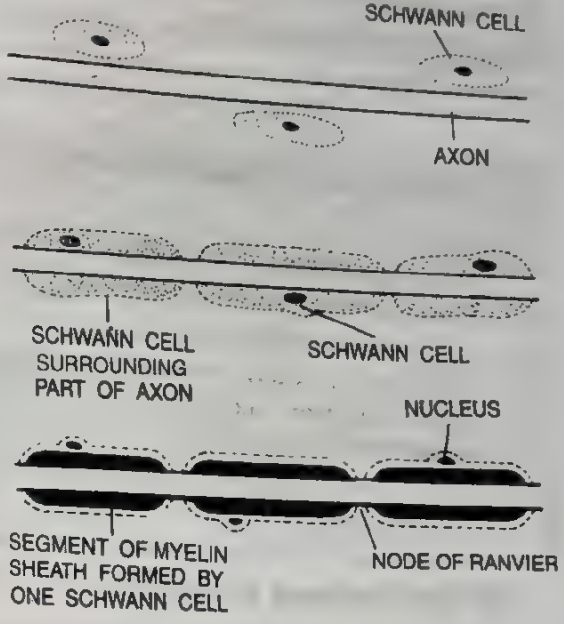


Fig. 7.39. Stages in the formation of the myelin sheath by a Schwann cell.

When an impulse travels along a medullated nerve fibre, it does not proceed uniformly along the length of the axis cylinder, but jumps from one node of Ranvier to the next. This is called the **saltatory conduction** of impulses. Thus, the conduction of impulses is faster in medullated nerve fibres.

Formation of Myelin Sheath (Fig. 7.40). An axon lying near a Schwann cell invaginates into the cytoplasm of the Schwann cell. The plasma membrane of a Schwann cell extends and becomes greatly elongated and comes to be spirally wound around the axon, which is thus surrounded by many layers of plasma membrane. These layers form **myelin sheath** consisting of alternating concentric layers of lipid and protein materials. Outside the myelin sheath, an additional sheath, called the **neurilemma** is formed. In fact the neurilemma is Schwann cell cytoplasm which is also called Schwann cell sheath. Schwann cell nucleus is also present in a segment of myelin sheath.

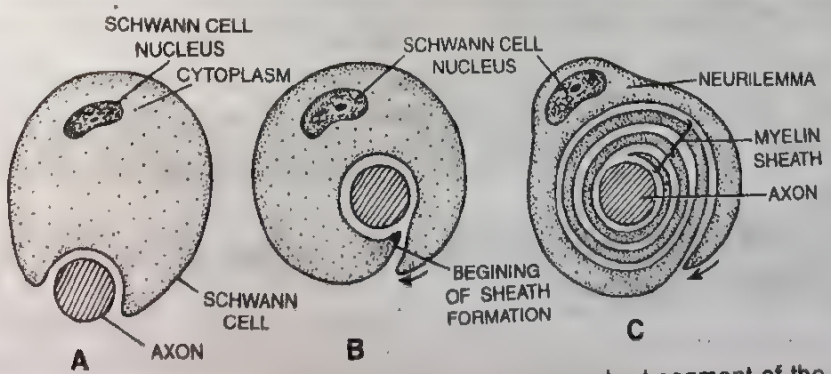


Fig. 7.40. Scheme to show that one Schwann cell forms a short segment of the myelin sheath.

(ii) **Non-medullated (= Non-myelinated) Nerve Fibres.** A non-medullated nerve fibre consists of an axis cylinder surrounded by neurilemma and connective tissue. The nuclei cause swelling along the fibre. Under electron microscope, a trace of myelin is seen around the axon. The non-medullated nerve fibres form **grey matter**. These fibres do not have the nodes of Ranvier and internodes. They also lack collateral fibres. The non-medullated nerve fibres are found in the autonomic nerves. They conduct nerve impulses much slower than the medullated nerve fibres.

Differences between Medullated and Non-medullated Nerve Fibres

Medullated (Myelinated) Nerve Fibres	*Non-medullated (Nonmyelinated) Nerve Fibres*
1. Medullary sheath is present.	1. Medullary sheath is absent.
2. They appear white in fresh state.	2. They appear grey in fresh state.
3. Nodes of Ranvier are present at intervals.	3. Nodes of Ranvier are absent.
4. Collateral nerve fibres are present.	4. Collateral nerve fibres are absent.
5. They are generally present in the white matter of brain and spinal cord and in cranial and spinal nerves.	5. They are present in autonomic nerves.
6. They carry impulses faster than non-medullated nerve fibres.	6. They carry impulses slower than medullated nerve fibres.

(B) On the basis of Function, the nerve fibres are again of two types :

(i) **Afferent (= Sensory) Nerve Fibres.** They carry nerve impulses from the sense organs to the central nervous system (brain and spinal cord).

(ii) **Efferent (= Motor) Nerve Fibres.** They carry nerve impulses from the central nervous system to the effector organs (muscles and glands).

Neuron Polarity. Nerve fibres carry impulses in one direction only from dendrites to cyton and hence to the axon. Thus one end of a neuron receives an impulse and the other end discharges it. This property of neuron is called **neuron polarity**. It can be explained with the examples of **afferent** (sensory) nerve fibres and **efferent** (motor) nerve fibres. The former carry nerve impulse from the sense organs to the central nervous system and the latter carry the nerve impulses from the central nervous system to the effector organs.

Grey and White Matter. The nervous tissue which forms the brain and spinal cord is of two types : **grey matter** and **white matter**. The grey matter consists of cell bodies of neurons, their dendrites and proximal ends of their axons. Most of the fibres within the grey matter are non-medullated. Grey matter looks grey in fresh state. The white matter looks white in fresh state which consists predominantly of medullated nerve fibres. Neuroglia (to be described ahead) and blood vessels are present in both grey and white matter.

The isolated masses of grey matter present anywhere in the central nervous system are called **nuclei**. Infact, nuclei are groups of cell bodies of neurons. Aggregations of the cell bodies of neurons may also be found outside the central nervous system. Such aggregations are called **ganglia**.

In general, the white matter carries impulses from one part of the body to another and the grey matter integrates the impulses.

Nerves

A nerve consists of several bundles of nerve fibres called **fasciculi**. Each fasciculum (sing. of fasciculi) is surrounded by a layer of connective tissue called the **perineurium**. The

perineurium is made up of flattened cells and collagen fibres (white fibres). Each nerve fibre is surrounded by a layer of connective tissue called the **endoneurium**. The endoneurium contains collagen fibres, fibroblasts, Schwann cells, endothelial cells and macrophages. A dense layer of connective tissue that surrounds the entire nerve is called the **epineurium**. The epineurium contains fat which cushions nerve fibres. Loss of this fat can lead to pressure on nerve fibres and paralysis.

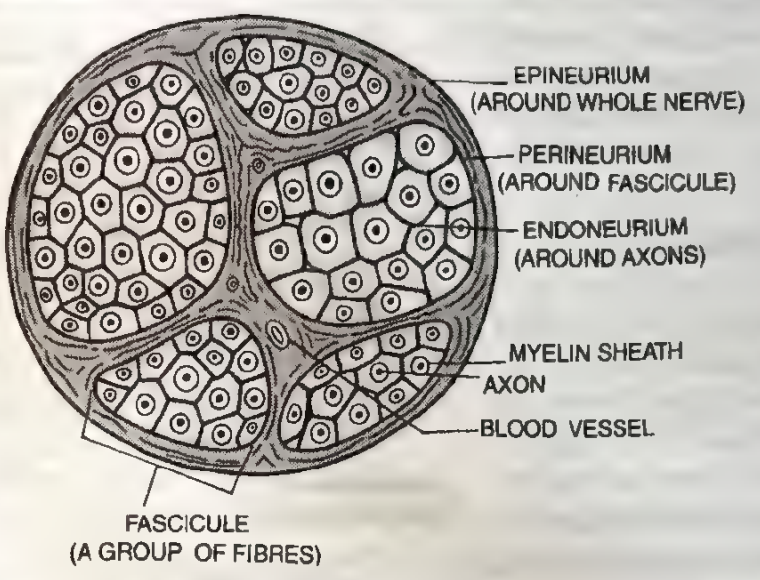


Fig. 7.41. T.S. of a nerve.

Types of Nerves. The nerves are of three types according to the nature of the fibres they are composed of :

(i) **Sensory (= Afferent Nerves)**. They contain sensory fibres. Olfactory, optic and auditory cranial nerves are sensory nerves.

(ii) **Motor (= Efferent) Nerves**. They contain motor nerve fibres. Oculomotor, pathetic, abducens, spinal accessory and hypoglossal cranial nerves are motor nerves.

(iii) **Mixed Nerves**. They contain both sensory and motor nerve fibres. Trigeminal, facial, glossopharyngeal and vagus cranial nerves are mixed nerves. Most of spinal nerves are mixed nerves.

2. Neuroglia (= or Neuroglial Cells or Glial Cells ;

Neuroglia (*neuro* = nerve; *glia* = glue) or neuroglial cells are specialised cells found in the brain and spinal cord supporting the neurons and their fibres. About 50 percent of all brain cells are neuroglial cells. They may be divided into two major catagories : Macroglia (= large glial cells) and microglia (= small glial cells).

(a) **Macroglia (= Large glial cells)**. They are formed from the ectoderm of the embryo and are of two types : astrocytes and oligocytes.

(i) **Astrocytes** (*astro* = Star ; *cyte* = cell). These cells are star shaped that give off a number of processes. They may be subdivided into fibrous and protoplasmic astrocytes.

Fibrous Astrocytes. These are mainly seen in white matter of CNS. Their processes are thin and are asymmetrical.

Protoplasmic Astrocytes. These are mainly seen in grey matter of CNS. Their processes are thicker than those of fibrous astrocytes and are symmetrical.

The astrocytes are thought to separate and provide mechanical support to the neurons. They also insulate adjacent neurons so that impulses pass from one neuron to the next only over the synapse where packing cells are missing. Astrocytes communicate with one another through calcium channels. Astrocytes play a role in maintenance of the blood brain barrier. They are also responsible for repair of damaged areas of nervous tissue.

(ii) **Oligodendrocytes** (= *Oligo* = few; *dendro* = tree). These cells have rounded nucleus. The cytoplasm is rich in mitochondria, microtubules and glycogen. They have fewer and shorter cell processes. They occur in two distinct areas ; near the medullated nerve fibres and near the surfaces of the somata (pl. of soma) of neurons. Oligodendrocytes form myelin sheaths around the axons that lie with the central nervous system (brain and spinal cord).

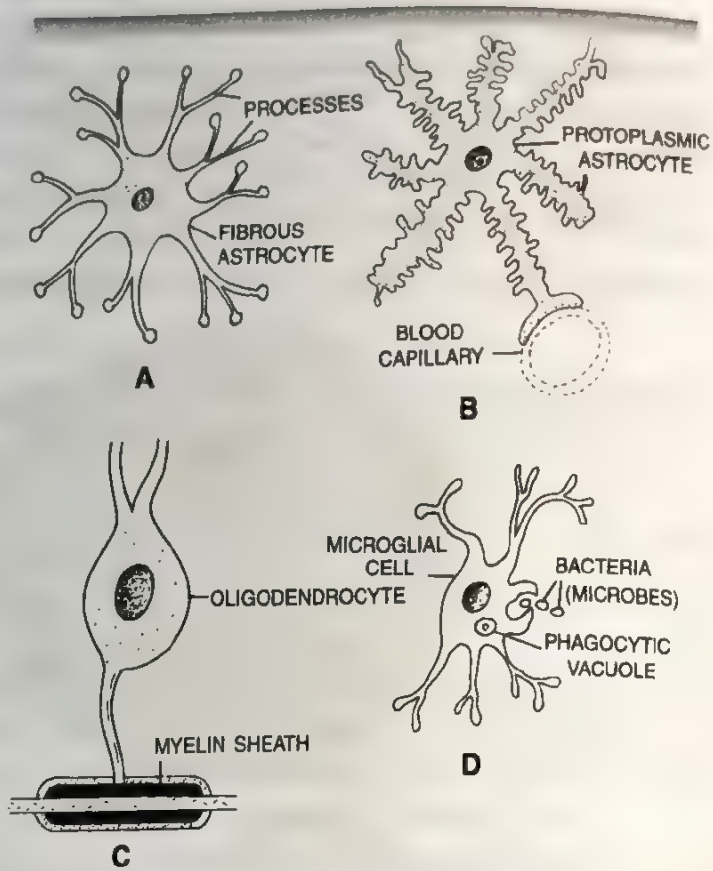


Fig. 7.42. Different kinds of neuroglial cells.
A, Fibrous astrocyte. B, Protoplasmic astrocyte.
C, Oligodendrocyte. D, Microglial cell.

- In addition to above mentioned macroglia the following cells also resemble the macroglia.
- **Glioblasts.** They are embryonic or postnatal (after birth) stem cells capable of differentiating into macroglial cells.
- **Pituicytes.** These cells are found in the posterior lobe of the pituitary gland. They are similar to astrocytes in some aspects.
- **Muller cells.** They are present in the retina and have many features in common with astrocytes.
- **Bergmann glial cells.** These cells are found in the cerebellum of the brain. In many respects they have the appearance of a primitive glial cell type.

(b) **Microglia** (= **Microglial cells or Small glial cells**). Microglia (*micro*= small; *glia* = glue) or microglial cells are *formed from the mesoderm of the embryo*. They are probably derived from the monocytes that invade the brain during foetal life. These are the smallest neuroglial cells. They are more numerous in grey matter than in white matter. Microglial cells have short and fine processes. They engulf and destroy microbes and cellular debris. Thus they are phagocytic and also act as scavengers. They may migrate to area of injured nervous tissue and function as small macrophages.

Differences between Neurons and Neuroglia

Neurons (Nerve cells)	*Neuroglia (Glial cells)*
1. Neurons possess two types of processes : axon and dendron.	1. Neuroglia have one type of several processes.

2. Neurons form synapse. 3. They conduct the nerve impulses. 4. All neurons arise from the ectoderm of the embryo.	2. They do not form synapse. 3. They form a packing around the nerve cells in the central nervous system. Some neuroglia cells are phagocytic in nature. Some of these cells act as scavengers. 4. Macroglia arise from the ectoderm and microglia from the mesoderm of the embryo.

• Neuroglia are of clinical interest because they are a common source of tumors of the nervous system.

3. **Ependymal Cells (= Ependyma).** These cells are arranged as an epithelial layer, one cell thick, which lines the ventricles (cavities of the brain) and the central canal of the spinal cord. The cells vary from squamous to columnar according to their location. Their free surface bears numerous microvilli and cilia. The microvilli help in the absorption of cerebrospinal fluid. The movements of the cilia contribute the flow of the cerebrospinal fluid. The ependymal cells possess one or more long processes towards opposite side which penetrate the nervous tissue.

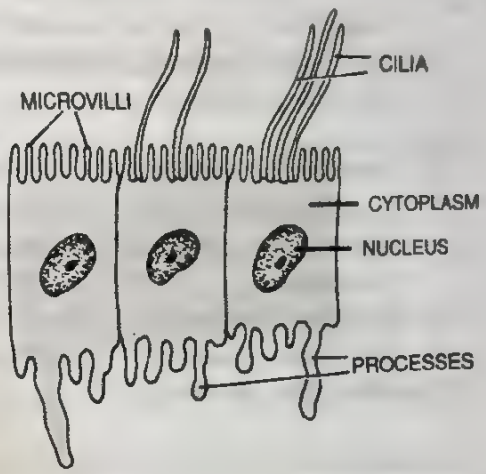


Fig. 7.43. Ependymal Cells.

4. **Neurosecretory Cells.** These specialized nerve cells function as endocrine organs. They release chemicals from their axons into the blood instead of synaptic cleft. Neurosecretory cells of the hypothalamus of the vertebrate brain secrete **neurohormones** (= releasing factors). These neurohormones are carried from the hypothalamus to the anterior lobe of the pituitary gland where they regulate the secretion of pituitary hormones such as ACTH, TSH, GH, LH, FSH and prolactin.

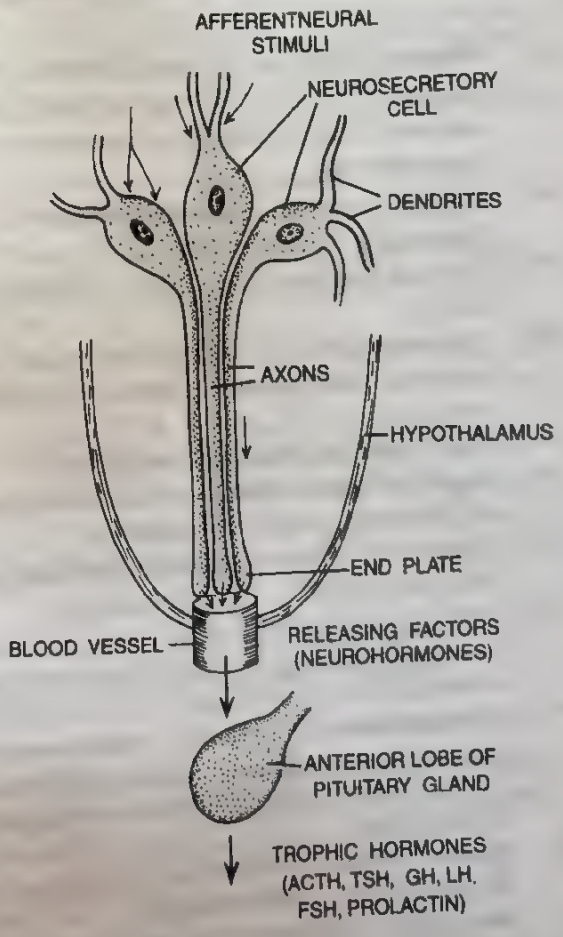


Fig. 7.44. Neurosecretory Cells.

Functions of Neural Tissue

The neural tissue is meant for reception, interpretation and transmission of information. The sensory cells receive stimuli. The sensory neurons carry sensory nerve impulses to the interneurons which send motor impulse through motor neurons to the effectors (muscles and glands). The neural tissue co-ordinates and integrates the activities of various body parts. This tissue is also seat of experiences, memories, etc.

ADDITIONAL INFORMATION

- **Types of Anaemia.** Anaemia is a condition in which the blood is deficient in the number of red blood corpuscles, in haemoglobin content or in total volume of blood. Anaemias are of many types. Some important anaemias are mentioned below.

1. Aplastic Anaemia	Lack of a functioning bone marrow.
2. Erythroblastosis foetalis	Rh positive RBCs of foetus are attacked by antibodies from an Rh negative mother.
3. Haemorrhagic Anaemia (Blood loss Anaemia)	Excessive bleeding
4. Haemolytic Anaemia (Haemolysis)	Rupture of RBCs.
5. Hereditary spherocytosis	Very small RBCs, spherical in shape rather than biconcave
6. Microcytic Anaemia (Iron Deficiency Anaemia)	Deficiency of iron
7. Megaloblastic Anaemia (Macrocytic Anaemia)	Deficiency of Folic acid and Vitamin B_{12}.
8. Pernicious Anaemia	Deficiency of vitamin B_{12}.
9. Nutritional Anaemia	Inadequate food.
10. Sickle-Cell Anaemia	Hereditary disorder (Gene mutation). RBCs contain abnormal type of haemoglobin called *haemoglobin S*. RBCs sickle shaped.
11. Septicemia	Blood poisoning
12. *Thalassaemia (Cooley's Anaemia)	Hereditary disorder (Gene mutation). Reduced haemoglobin synthesis, haemolysis and ineffective erythropoiesis.

- **Hertwig** (1883) introduced the term **"mesenchyma"** for all the tissues of adult body derived from mesoderm (=embryonic mesenchyme).
- Fat cells can be stained by Sudan III, Scharlach R, osmic acid.
- Largest cavity of the body — Abdominal cavity.
- **Chondroclast** A multinucleated cell involved in the reabsorption of calcified cartilage.
- **Chondrology.** Study of cartilage.
- **Types of cells in Bone** — (i) Osteoblasts (ii) Osteocytes (iii) Osteoclasts.
- **Osteolysis.** Softening, absorption and destruction of bone by osteoclasts.
- **Osteotomy** (Gr. *Osteon* = bone, *tome* = incision). Cutting a bone with a saw or chisel.
- **Osteoporosis** (Gr. *osteon* = bone, *poros* = pore, *oris* = condition). Atrophy of bones, occurs in post menopausal women and elderly men.
- Kinds of skeletal tissue in vertebrates— (i) Notochord (ii) Cartilage (iii) Bone
- **Histolysis.** Disintegration of a tissue.
- **Haemolymph.** Colourless blood of arthropods present in the **haemocoel** (body cavity filled with blood)
- **Haematology.** Medical specialty in all aspects of blood.
- **Haemorrhage.** Flow of blood from an injured blood vessel.
- **Haemolysis.** Dissolution or destruction of red blood corpuscles with a release of haemoglobin.
- **Haemozoon.** A blood-inhabiting parasitic animal such as *Trypanosoma, Wuchereria*.
- **Histogenesis** is the process of tissue development.
- Epithelia are highly regenerative.
- One third of body proteins in man are said to be collagen.
- **Sharpey's fibres** are bundles of collagenous fibres that pass into the outer circumferential lamellae of bone or the cementum of teeth. They provide strength to the bone and teeth.
- **Prothrombin** and **fibrinogen** are largest blood proteins. **Albumins** are smallest blood proteins.

*Thalassaemia was discovered by Cooley in 1927.

- **Phagocytosis** was discovered and named by **Metchnikoff** (Winner of 1908 Nobel Prize).
- Each neuron arises in the embryo, from a single **neuroblast** (cell).
- **Serotonin** is thought to reduce stress.
- Certain neutrophils in female mammals possess a small spherical lobe attached to their nucleus by a stalk. This lobe is called **drumstick.**
- The cells obtained by a smear from the oral mucous membrane of a normal female have been found to possess a small mass of deeply staining chromatin lying against the nuclear membrane. It is called **Barr body** (Barr—name of scientist). Drumstick or Barr body represents an inactivated X-chromosome and is called sex chromatin.
- **Necrosis.** Area of dead tissue surrounded by a healthy area.
- Sarcosomes are muscular mitochondria.
- Mitochondria are present in large amount in liver and kidney.
- Metals required in synthesis of haemoglobin are iron, copper and cobalt.
- Cholesterol concentration is highest in cardiac muscle.
- Phospholipids concentration is maximum in cardiac muscle.
- Circulation of lymph is influenced by pressure gradient, muscular action and respiratory movements.
- Nerve cells cannot be grown under tissue culture conditions.
- Wrinkling in old age is due to collagen fibres with diminishing rigidity.
- At the nodes of Ranvier only Na^+ channels are present.
- **Dandruff.** Flaked off superficial keratinised dead layers of skin epidermis.
- The muscles change gradually from voluntary to involuntary in the upper part of oesophagus.
- A myelin sheath is not found in the nerve fibres of cyclostomes.
- Eosinophils were first discovered by **Paul Ehlrich.** A new form of eosinophil has been discovered by **Jacob S. Hanker** (1980). This cell has been named **"medusa cell"** as its tentacle-like processes (projections) make it look like a medusoid jelly fish. With these processes the medusa cell moves and engulfs cells other than bacteria.
- **Anthropology.** Study of the origin and development of humans
- **Hyperthelia** . Existence of more than two nipples.
- **Gynaecomastia.** Presence of functional mammary glands in male.
- **Colostrum.** A yellowish, antibody rich, liquid first secreted by breasts after the birth of an infant.
- Most common muscle of inspiration is **diaphragm.**
- Most radiosensitive blood cell is **lymphocyte.**
- Most radioresistant blood cell is **platelet.**
- Most radiosensitive tissue of body is **bone marrow.**
- Least radiosensitive tissue of body is **nervous tissue.**
- **Neurology.** Science dealing with the neural system and its disorders.
- **Neurohistology.** Microscopic anatomy of the neural system.
- Target organ of *Mycobacterium leprae* is **Schwann cells** of peripheral nerves.
- **Neurolymph.** Cerebrospinal fluid filling the cavities of central neural system (brain and spinal cord).
- **Blood-brain Barrier.** It prevents passage of certain substances from the blood to the nervous tissue. It is due to the reduced permeability of the blood capillaries in the nervous tissue. It is thought that neuroglia also play a role in maintaining the blood-brain barrier.

NCERT TEXTBOOK QUESTIONS WITH ANSWERS

1. What are the cellular components of blood ?

   ✓ The cellular components of blood are (i) red blood corpuscles (R.B.Cs) (ii) White blood corpuscles (W.B.Cs) and (iii) blood platelets. White blood corpuscles are further differentiated as **agranulocytes** (monocytes and lymphocytes) and **granulocytes** (basophils, eosinophils and neutrophils).

2. What are the following and where do you find them in animal body.

   (a) Chondrocytes (b) Axons (c) Ciliated epithelium.

   ✓ (a) **Chondrocytes.** Chondrocytes are found in the matrix (ground substance) of the cartilage. Cartilage is found in the pinna, tip of the nose, intervertebral disc, etc.

(b) **Axons.** Each axon arises from cyton of the nerve cell (neuron) and conducts nerve impulses away from the cell body. Axons are present in entire body.

(c) **Ciliated epithelium.** It consists of cells that bear cilia on the free surface. It is present in certain parts of nephrons of kidneys, nasal passage, oviducts (Fallopian tube), etc.

3. Mark the odd one in each series :
   (a) Areolar tissue : blood ; neuron; tendon.
   (b) R.B.C.; W.B.C. ; platelets ; cartilage.
   (c) Exocrine ; endocrine ; salivary gland ; ligament.
   ✓ (a) neuron (b) cartilage (c) ligament
4. Match the terms in column I with those in column II.

Column I	Column II
(a) compound epithelium	(i) Bone
(b) Osteocytes	(ii) Skin

   ✓ (a)— (ii) (b)— (i)
5. Distinguish between
   (a) Simple epithelium and compound epithelium.
   (b) Cardiac muscle and striated muscle.
   (c) Dense regular and dense irregular connective tissues.
   (d) Adipose and blood tissue.
   (e) Simple gland and compound gland.
   ✓ (a) Refer to the text Differences between Simple epithelium and Compound epithelium.
   (b) Refer to the text Differences between Muscles fibres.
   (c) Refer to the text
   (d) Refer to the text

Adipose Tissue	*Blood Tissue*
1. It is a loose connective tissue. 2. The matrix has fibres. 3. It is meant for storage and metabolism of fats.	1. It has a fluid connective tissue. 2. The matrix does not have any fibres. 3. It is meant for circulation of various substances and respiratory gases.

   (e) Refer to the text
6. Describe various types of epithelial tissues with the help of labelled diagrams.
   ✓ Refer to the text Epithelial Tissues.

TEST QUESTIONS

One Mark Questions (With Answers)

1. Why intestinal mucosa has microvilli ?
   ✓ To increase the absorptive surface.
2. What are Mucus secreting cells called ?
   ✓ Goblet cells
3. Name any one heterocrine gland ?
   ✓ Pancreas
4. Which protein constitutes bone matrix ?
   ✓ Ossein
5. What is the use of cholesterol in the blood ?
   ✓ Cholesterol is used in the synthesis of cell membranes, vitamin D, bile salts and steroid hormones.
6. Why blood plasma is pale yellow in colour ?
   ✓ Due to bilirubin
7. Neurons are packed around with some cells. Name ?
   ✓ Neuroglia or Glia cells
8. What are Myoblasts ?
   ✓ Muscle forming cells.

Two Mark Questions (With Sample Answers)

1. How does a metazoan body become multicellular ?
   ✓ In sexual reproduction, **male gamete** (sperm) and **female gamete** (ovum) fuse to form unicellular **zygote.** The zygote undergoes mitosis to form multicellular **embryo.** All the cells of an early embryo are similar. As the embryonic cells further divide, they get differentiated and by the end of embryonic development all varieties of the cells are formed in the young adult body.
2. Does lymph help in maintaining volume of blood and how ?
   ✓ Yes, lymph maintains the volume of the blood. As soon as the volume of the blood reduces in the blood vascular system, the lymph rushes from the lymphatic system to the blood vascular system.
3. Write the four types of animal tissues based on location & function?
   ✓ 1. Epithelial tissue 2. Connective tissue 3. Muscular tissue 4. Nervous tissue
4. Where is yellow bone marrow present? What is its fate in the case of anaemia ?
   ✓ It is present in shafts of long bones and has much fatty tissue. It produces blood corpuscles in emergency. Yellow bone marrow may be replaced by red bone marrow in **anaemia.**
5. How eosinophils can destroy parasitic forms ?
   ✓ Eosinophils can attach themselves to parasitic forms and cause their destruction by liberating lysosomal enzymes on their surface.
6. Name the tissue that lines the intestinal mucosa. State the advantage of this tissue being present there.
7. Name the tissue that lines the Fallopian tubes. State any one advantage of this tissue being present there.

Three Mark Questions (Short Answer Type)

1. Enumerate the cell types of the connective tissue.
2. What is the difference between blood and lymph.
3. Write the functions of blood plasma ?
4. Describe the structure of the multicellular neuron.

Five Mark Questions (Long Answer Type)

1. Describe the composition and functions of blood.
2. (i) Give an account of the structure of different kinds of neurons. (ii) Describe neurosecretory neurons.
3. Describe the different types of muscle fibres.

Multiple Choice Questions (With Answers)

(1) Intercalated discs occur (a) between neurons (b) between cardiac muscle fibres (c) at the junction of muscle and nerve cells (d) in striped muscle. *(MPPMT 2000)*

(2) Which of the following is multinucleated ? (a) Nonstriated muscle (b) Striated muscle (c) Renal tissue (d) Nervous tissue (e) Erythrocytes of reptiles. *(Kerala PMT 2001)*

(3) Nasal septum contains *(CBSE 2001)*
(a) fibrous cartilage (b) elastic cartilage (c) calcified cartilage (d) hyaline cartilage

(4) Lymph contains (a) everything like blood except RBC and few blood proteins (b) serum and WBC (c) blood plasma (d) WBC and RBC

(5) In which of the following tissues is the matrix is not product of synthesis of its cells ? (a) Vascular tissue (b) Osseus tissue (c) Loose connective tissue (d) Adipose tissue. *(Karnataka 2003)*

(6) Basophils help the body defence by (a) phagocytosis of pathogens (b) cell mediated and antibody immunity (c) inhibit allergic reaction (d) heparin secretion for preventing thrombosis. *(Orissa 2003)*

(7) The formation of erythrocytes in foetus takes place in *(Karnataka 2003)*
(a) liver and spleen (b) red bone marrow (c) blood plasma (d) sarcoplasm.

(8) Myelin sheath is mainly made of *(Manipal 2003)*
(a) protein (b) phospholipids (c) proteins (d) carbohydrates.

(9) Cells of germinal epithelium are *(CET Chd. 2003)*
(a) cuboidal (b) columnar (c) squamous (d) ciliated.

(10) Antibodies are formed by *(CET Chd. 2003)*
(a) plasma cells (b) histiocytes (c) mast cells (d) none of these.

(49) Stratified epithelium is found in (a) seminiferous tubule (b) Fallopian tube (c) nasal cavity (d) kidney tubules. *(J & K CET 2011)*

(50) Cardiac muscles are (a) striated and voluntary (b) striated and involuntary (c) smooth and vountary (d) smooth and involuntary. *(West Bengal JEE 2011)*

(51) Inner surfaces of bronchi, bronchioles and Fallopian tubes are lined by (a) cubical epithelium (b) columnar epithelium (c) squamous epithelium (d) ciliated epithelium. *(West Bengal JEE 2011)*

(52) The non-keratinized stratified squamous epithelium is present in (a) epidermis of skin of hand and vertebrate (b) vagina and cervix (c) oral cavity (d) vagina, cervix oral cavity. *(Orissa JEE 2011)*

Assertion and Reason Type Questions

In each of the following questions two statements are given, one is Assertion (A) and other is Reason (R). For the (A) and (R) statements, mark the correct answer as

(A) If both **A** and **R** are true and **R** is the correct explanation of **A**.

(B) If both **A** and **R** are true but **R** is not the correct explanation of **A**.

(C) If **A** is true but **R** is false.

(D) If both **A** and **R** are false.

(1) **Assertion** : Bone and cartilage are rigid connective tissues.
Reason :Blood is a connective tissue with fluid (plasma) matrix.
A B C D

(2) **Assertion** : Haversian canals run longitudinally in the mammalian bone.
Reason : Haversian canals contain blood vessles and nerves. Each canal supplies the lamellae of its own Haversian system.
A B C D

(3) **Assertion** : Nerve fibres in the CNS can regenerate after injury.
Reason : They have around them neurilemma that brings about regeneration.
A B C D

(4) **Assertion** : Platelets play an important role in blood clotting.
Reason : In the blood oozing from an injury, the platelets disintegrate and release thromboplastin that initiates clotting.
A B C D

(5) **Assertion** : Whales can lie in cold water as they have a thick coat of blubber under the skin.
Reason : Blubber consists of adipose tissue that insulates the body.
A B C D

(6) **Assertion** : The bone disorder called osteoporosis results from the loss of calcium and phosphate from the bone matrix.
Reason : In osteoporosis, bone material is destroyed by osteoclasts more quickly than it is laid down by osteoblasts.
A B C D

ANSWERS

Multiple Choice Questions (With Answers)

(1) —b (2) —b (3) —d (4) —b (5) —a (6) —d (7) —a (8) —b (9) —a (10) —a
(11) —c (12) —b (13) —c (14) —d (15) —a (16) —c (17) —b (18) —c (19) —b (20) —b
(21) —b (22) —b (23) —a (24) —c (25) —b (26) —c (27) —c (28) —b (29) —c (30) —c
(31) —e (32) —b (33) —a (34) —d (35) —a (36) —b (37) —a (38) —c (39) —d (40) —c
(41) —b (42) —c (43) —a (44) —c (45) —b (46) —b (47) —b (48) —c (49) —c (50) —b
(51) — d (52) —d

Assertion and Reason Type Questions

(1) —B (2) —B (3) —D (4) —A (5) —A (6) —A